DEPARTMENT OF THE INTERIOR
Hubert Work, Secretary

U. S. GEOLOGICAL SURVEY
George Otis Smith, Director

Professional Paper 140

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

1925

W. C. MENDENHALL, CHIEF GEOLOGIST

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

CONTENTS

[The letters in parentheses preceding the titles are those used to designate the papers for advance publication]

ILLUSTRATIONS

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY, 1925

GEOLOGY OF THE LATAH FORMATION IN RELATION TO THE LAVAS OF COLUMBIA PLATEAU NEAR SPOKANE, WASHINGTON

By J. T. PARDEE and KIRK BRYAN

SUMMARY

The name Latah formation is proposed for a series of beds consisting mostly of clay and shale and of fresh-water origin that are found near Spokane, Wash., and that contain an abundant middle or lower Miocene flora. The formation is found in Latah Creek valley for 10 miles south of Spokane, on tributaries of Little Spokane River for 20 miles north of the city, and in places in Spokane Valley for 8 miles northwest and 5 miles east of the city. It occurs also in at least one place in the broad, open valleys of the mountains near Coeur d'Alene, Idaho. These beds rest upon a rough surface of granitic and schistose rocks of unknown age, attain a maximum thickness of 1,500 feet, and are overlain by "rim rock" basalt flows, probably Miocene; "valley" flows, probably later Tertiary; and gravel of Pleistocene age. Sills and dikes, which represent some of the conduits through which the "rim rock" basalt rose to the surface, cut and to a small extent deform the Latah beds, which otherwise retain their original horizontal attitude.

During Latah time the lava floods of the Columbia Plateau, advancing from the west, were held back from the Spokane area by a ridge, the highest parts of which now form the hills near Cheney, Marshall, and Medical Lake. The drainage outlet of this area was thus gradually obstructed by the lava, and the sediments here described were accumulated. Eventually the lava piled up until the "rim rock" flows were enabled to cross the protecting ridge and to overspread the area of Latah sediments.

The "rim rock" flows consist of olivine basalt that shows very conspicuous columnar jointing. They are considered to be of Miocene age but are doubtless younger than the Yakima basalt. West of the submerged ridge they are apparently indistinguishable from the great series of flows that make up the Columbia Plateau.

After a time interval measured by the cutting of valleys through the "rim rock" basalt and to a known depth of 800 feet into the Latah formation another series of basalt flows, referred to as "valley" flows, were extruded. These flows occupy parts of the erosional valleys and rest unconformably upon the Latah, exhibiting at the contact "pillow structure" and other characteristic features. They are distinguished from the "rim rock" flows largely by their topographic position, by a more varied jointing, and by the absence of olivine.

INTRODUCTION

The Latah formation, as a whole, has been studied only in the general vicinity of Spokane, Wash., although there is evidence, from collections of fossil leaves, that it extends eastward into the open valleys near Coeur d'Alene, Idaho. Much information concerning this formation has been gathered by local students, whose work in collecting fossil leaves is further noted below. The work of the writers has been incidental to or a part of other geologic work and consisted in a study of the Pleistocene features of Spokane Valley by Mr. Pardee at times during 1922 and 1923 and a geologic examination of the general area by Mr. Bryan, in connection with his work on the Columbia Basin irrigation project, in 1923. The unexpected extent of the leaf-bearing beds and their interesting relations to the lava flows seem to justify as complete a description of the formation as is now possible and an account of its fossil localities. The large flora is described by F. H. Knowlton on pages 17–50. As elsewhere noted, specimens of the basalts were studied under the microscope by F. C. Calkins, who also read the text and offered helpful criticisms. Edward Sampson studied under the microscope specimens from the Latah formation and from the fragmental rock inclosing the "pillows" of the "valley" flows.

COLLECTION AND OCCURRENCE OF THE FOSSILS

The fossil plant remains from the beds described were mostly collected and given to the United States Geological Survey and the United States National Museum by Mr. Henry Fair, Mr. C. O. Fernquist, and Prof. T. A. Bonser, of Spokane, and by Mr. H. J. Rust, of Coeur d'Alene. A small but valuable part of the collection was contributed by Prof. Thomas Large, of Spokane, who shares the credit for collecting it with Miss Doris Burchett, a high-school student. Dr. R. W. Chaney, of the Carnegie Institution of Washington, added a valuable lot of these plant remains which he had collected several years before, and the whole was further enriched by a large number of specimens obtained by Mr. Bryan in 1923. To all the local collectors much credit is due for the discrimination and care with which they selected and marked the specimens.

The fossils are unusually well preserved. As described by Mr. Knowlton, they represent an ancient and varied flora that was very different from the native vegetation growing about Spokane to-day. The collection is of particular value because it comes from a locality not before studied in detail and gives evidence bearing on the geologic age of the vast lava flows that form the Columbia Plateau of Oregon, Washington, and Idaho.

Fossil plant remains have been known in the neighborhood of Spokane for a considerable time and were mentioned by Russell [1] as long ago as 1897, but so far as the writers are aware no description of the fossils or their occurrence has been published heretofore. From time to time the excavation of street and railroad cuts has exposed fossil-bearing beds, and a few years ago local interest in fossils was somewhat stimulated by the finding in the Division Street cut of a charred tree trunk inclosed between two ancient lava flows. Recently Professor Bonser, aided by his pupils, has collected a large number of the fossil leaves and other remains, which he has placed on exhibition in the Spokane Public Museum. The field work of the other collectors was done at odd times from 1920 to 1923.

The larger part of the collection was obtained at the following places: Deep Creek half a mile above its mouth; in the cuts of the Spokane, Portland & Seattle Railway and the Chicago, Milwaukee & St. Paul Railway in Spokane west of Latah Creek; at Thor Street and Twelfth Avenue, Spokane; and at the Edwards ranch, Stanley Hill, near Coeur d'Alene, Idaho. The remainder came from a clay pit at the edge of the Spokane Valley, 2 miles south of Vera; from a well a quarter of a mile west of Mica; and from outcrops at the Schuele ranch and in a ravine, on the slopes south and southeast respectively of Fivemile Prairie. Fossil plant remains have also been found on the south side of Indian Canyon just above the falls, in Biglow Gulch about 2 miles northeast of Hillyard, in road cuts in sec. 31, T. 52 N., R. 44 E., and sec. 29, T. 51 N., R. 44 E., and in Spokane between Cannon Hill and Union Park and at the intersection of Thirteenth Avenue and Perry Street.

Most of the fossil-bearing localities mentioned are within a radius of 10 miles from Spokane, and all may be included in an area 10 or 20 miles wide that extends from Coeur d'Alene, Idaho, westward 35 to 40 miles along Spokane River. All the localities are shown on the index map (fig. 1). This area of fossiliferous beds lies about 150 miles east of Ellensburg, Wash., the nearest place at which plant-bearing beds associated with similar lavas have been found.[2] Other more distant areas in the general region that contain floras of somewhat similar occurrence are mentioned in the paper by Mr. Knowlton.

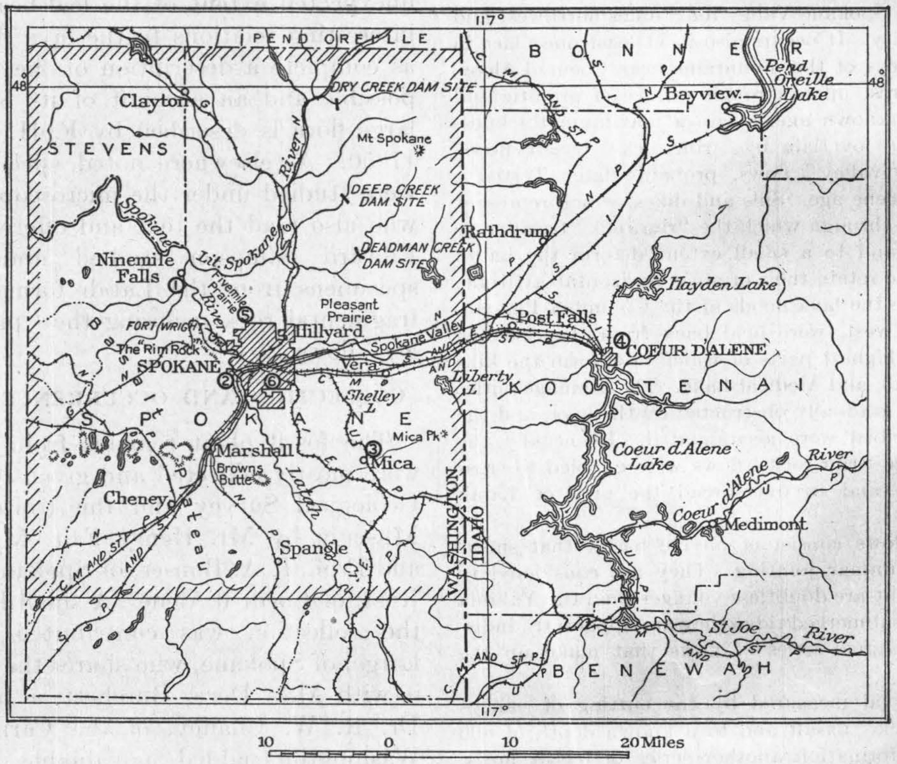


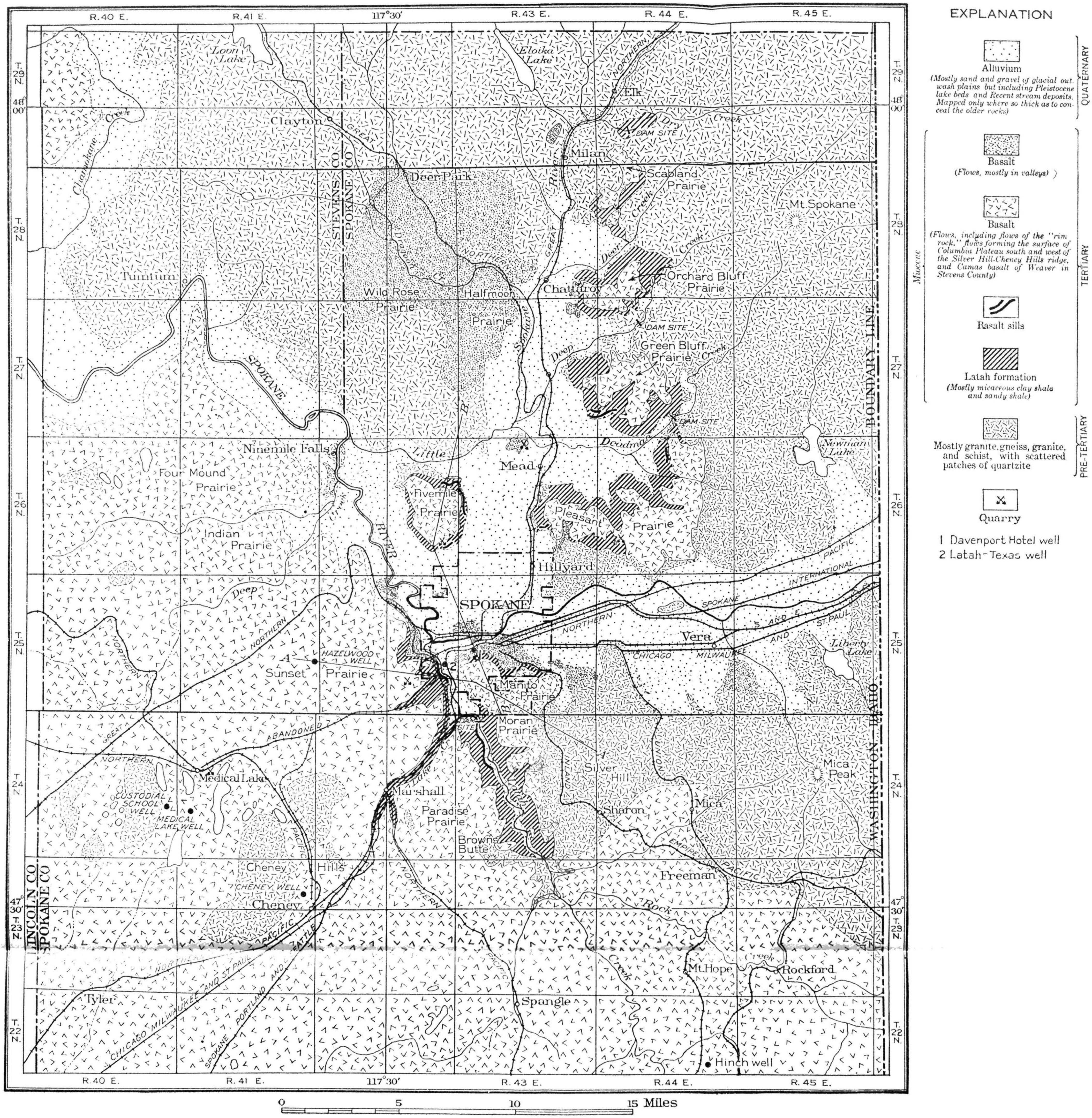
FIGURE 1.—Index map showing position of fossil localities near Spokane, Wash., and location of area covered by Plate I

SURFACE FEATURES OF THE REGION.

The area considered herein lies along the border between the Great Plains of the Columbia, or the Columbia Plateau, and the mountains of northern Idaho and northeastern Washington. It includes parts of the valleys of Spokane and Little Spokane rivers, together with adjoining parts of the mountains

[1] Russell, I. C., A reconnaissance in southeastern Washington: U. S. Geol. Survey Water-Supply Paper 4, p. 53, 1897.

[2] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), p. 3, 1902, Russell, I. C., A geological reconnaissance in central Washington: U. S. Geol. Survey Bull. 108, p. 103, 1893.



RECONNAISSANCE GEOLOGIC MAP OF AREA NEAR SPOKANE, WASH.

A—A′, B—B′, lines of sections in Figures 2 and 3 and the plateau. The general setting of the area is shown in Figure 1, and the area immediately adjacent to Spokane is shown on the geologic map (Pl. I).

Spokane lies at the northeast corner of the Columbia Plateau. From the hills east of the city this feature appears as a plain stretching away to the horizon on the south and west. It owes its general character to the fact that it is built up of vast lava flows that remain nearly as level as when they cooled. Because the liquid masses advanced upon a mountainous region the edge of the plateau is sinuous and irregular. South of Spokane it projects into the mountain valleys and retires around the intervening spurs like the coast line of a sea, and this fancied resemblance is increased by the fact that here and there isolated hills rise above the plain like off-shore islands. Westward from Spokane the present northern boundary of the plateau is the valley of Spokane River, a feature of more recent origin. North and east of the river isolated mesas or plateaus capped by basalt show that before the valley of Spokane River and its tributaries were cut that part of the plateau margin, like the stretch south of Spokane, was exceedingly sinuous.

In the neighborhood of Spokane the general altitude of the plateau is about 2,400 feet above the sea; its surface appears to be level or to slope gently northward, and it drains toward Spokane River. At a distance of 10 or 12 miles west of Spokane is an inconspicuous divide, beyond which the plateau descends gradually to the southwest for more than 100 miles. Considered in detail the plateau surface near Spokane is considerably roughened. The streams tributary to Spokane River have cut valleys into it several hundred feet deep, which exhibit crags, cliffs, and terraces at different levels.

The area immediately east and north of the Columbia Plateau is characterized by wide valleys, smoothly contoured slopes, and mountains of moderate height. Between Spokane and Coeur d'Alene the local relief ranges from 100 to as much as 3,000 feet. Farther east it is greater. The change from plateau to hills or mountains is generally abrupt, definite, and without gradations, but commonly a small depression is found between the edge of the basalt and the foot of the mountain slope.

From Spokane a wide depression extends east-northeastward into the mountainous area as far as the head of Pend Oreille Lake. It contains a level floor that in the vicinity of Spokane is about 2,000 feet above the sea, or 400 feet below the Columbia Plateau. Eastward the floor rises gradually, its general altitude in the neighborhood of Coeur d'Alene, about 30 miles from Spokane, being 2,300 feet. Along the sides of this depression in tributary valleys are several beautiful lakes, including Coeur d'Alene Lake, that are well known as summer resorts. So far as the writers are aware there is no name in use for this depression as a whole. For a distance of 15 or 20 miles east of Spokane it is known as Spokane Valley. Beyond this a part lying between Coeur d'Alene and Rathdrum, Idaho, is called Rathdrum Prairie, and the remainder is known by different names.

Spokane River, the outlet of Coeur d'Alene Lake, flows through Spokane Valley in a shallow trench to the falls at Spokane. Below this point it occupies a deep gorgelike valley, bordered by prominent cliffs and terraces, that extends northwest along the edge of the Columbia Plateau. This valley, which by reason of its generally rugged character contrasts strongly with the valley above the falls, or Spokane Valley proper, is commonly known as the gorge or "lower valley" of Spokane River.

On the north side of Spokane Valley opposite Spokane is a small table-land or plateau known as Fivemile Prairie (Pl. I). Its flat summit is nearly 2,400 feet in altitude, and its upper part is composed of two or more horizontal sheets of lava. Evidently it once formed a part of the Columbia Plateau, from which it has been cut off by Spokane River. Pleasant, Green Bluff, Orchard Bluff, and Scabland prairies are similar outliers of the plateau that extend north from Spokane on the east side of the valley of Little Spokane River. The general appearance of these table-lands or mesas may be judged from Plate II, *A*, a view of the northwest slope of Pleasant Prairie. Here and there east of Spokane on both sides of the valley are shelves at or near the 2,400-foot contour formed by patches of lava clinging to the sides of the valley. The most extensive one observed is at the north of Hayden Lake. Others appear on the shores of Coeur d'Alene Lake and along the lower courses of Coeur d'Alene and St. Joe rivers. All are interpreted as remnants of the highest and last of the lava flows that built the Columbia Plateau and once overspread Spokane Valley and its tributaries.

Patches of lava that form small masses and benches from 1,800 to 2,100 feet in altitude occur along Spokane River at Spokane, near Milan, near Chattaroy, on Half Moon Prairie, and near Deer Park. These isolated outcrops are interpreted as remnants of the plain formed by the most recent flow of the region as described on page 13.

Latah Creek and Deep Creek, which join the river below Spokane and drain adjoining parts of the Columbia Plateau, have excavated deep valleys similar in character to the valley of Spokane River below Spokane Falls. Viewed from Manito Prairie, the plateau remnant south of Spokane, across the deep valley of Latah Creek, the Columbia Plateau, bounded by its black cliffs, stretches out to the horizon, as shown in Plate II, *B*.

Out on the plateau 8 or 10 miles from Spokane are several hills that stand out faintly on the sky line. These "islands" or "steptoes" are knobs and ridges of granite and similar rocks that project through the lava. Together they form a broken chain of hills extending from Silver Hill west and northwest to Browns Butte, Marshall, Cheney, and Medical Lake. Probably to be included with them are two small knobs farther northwest, beyond Deep Creek. (See Pl. I.) These hills, as explained on page 10, mark the position of a buried ridge that for a time held back the advancing lava flows and permitted the leaf-bearing sediments to accumulate undisturbed in the neighborhood of Spokane. Finally, however, the lava overflowed and submerged the ridge until only its highest summits stood above the igneous flood.

ROCKS

GRANITE-SCHIST GROUP

The mountainous part of the area considered is composed chiefly of crystalline and metamorphic rocks, such as granite, gneiss, and schist, with small masses of quartzite. In addition rocks of this group form the encircling chain of hills that rise above the plateau from Silver Hill to Medical Lake. On the north side of Fivemile Prairie, in numerous places in the other "prairies" east and north of Spokane, and down the gorge on Spokane River, granite and granite gneiss crop out beneath the lava and the fossil-bearing shale, as shown on the geologic map (Pl. I). It is evident, therefore, that in addition to composing the hilly areas these rocks extend beneath the plateau as a basement or floor upon which the sediments and lavas rest. To judge by the degree of crumpling and metamorphism it exhibits, the schist is very ancient. The granitic rocks that intrude it are younger, but all members of this group are much older than the lava, the fossil-bearing shale, and the gravel that lie unconformably upon them. A detailed description of the granite-schist group as it occurs at Silver Hill, southeast of Spokane, is given by Collier,[3] and for Stevens County by Weaver.[4]

LATAH FORMATION

GENERAL FEATURES

The fossil-bearing beds that overlie the granite-schist group are distributed through an area extending from the mouth of Deep Creek east-southeastward to Coeur d'Alene, Idaho, and 20 miles north of Spokane to Dry Creek, near the town of Elk. Owing to the fact, however, that they are composed of soft and easily erodible materials, they have been largely washed away wherever they were not protected by a covering of basalt, and their areal extent therefore is small. (See Pl. I.) The vertical range of their exposures amounts to as much as 800 feet, the lowest, which is near the mouth of Deep Creek, being at an altitude of about 1,650 feet, and the highest, near Mica, at about 2,450 feet.

The fossil-bearing beds consist mostly of shale or clay, with a few layers of sand and gravel. The colors range from pale yellowish gray to lead-gray or bluish gray, the prevailing shades being rather dull. Locally the beds show pale tints of brown and streaks of rusty red. Glistening specks of white mica occur abundantly in most of the beds. The coarser layers are composed chiefly of quartz and feldspar grains derived by erosion from the rocks of the granite-schist group. No beds were observed to contain pebbles or grains of basalt. Approximate analyses made in the laboratory of the Geological Survey show the clays to contain from 45 to 70 per cent of silica and from 15 to 30 per cent of alumina.

A microscopic examination by Edward Sampson of specimens of the shale from the neighborhood of Latah Creek indicates that much of the finer-grained material composing the shales is of volcanic origin. These specimens contained sharp-edged grains of quartz and fresh grains of plagioclase feldspar and biotite mica that can hardly have been derived from the rocks of the granite-schist group and seem more likely to have been derived from showers of volcanic ashes of an andesitic type that fell in the region during the period of sedimentation. The lack of volcanic glass, so far unidentified in the specimens, is difficult to explain. The lamination of the beds indicates that the material of the ash showers was thoroughly reworked by streams and probably more or less mixed with the products of the erosion of the granite-schist highlands to the east.

In weathering the shale usually becomes brownish yellow and loses its lamination and jointing. Stains, spots, and seams of limonite are formed. Usually also there is a surface crust from a quarter of an inch to 2 inches thick composed of sand and limonite so hard that pieces ring under the hammer. The crust is frequently broken in plowing, and the flakes are picked up and piled in heaps at the edges of the fields. The clayey character of the weathered shale makes it a notable soil in a region where most of the soils are sandy. In some places the weathered surface of the shale is leached to a white impure kaolin, which retains, however, flakes of mica and leaf impressions. This white phase of the weathered surface and also the ordinary type are used near Spokane and at Vera for making common brick and tile.

Where the beds rest on the underlying granite gneiss they usually consist of arkosic gravel that grades by interbedding into the characteristic clay

[3] Collier, A. J., Tin ore at Spokane, Wash.: U. S. Geol. Survey Bull. 340, pp. 295-305, 1908.

[4] Weaver, C. E., The mineral resources of Stevens County, Wash.: Washington Geol. Survey Bull. 20, 1920.

shale. Clay with scattered small pebbles and clayey gravel were found interbedded with the typical clay shale in the test holes drilled in 1923 at the Latah Creek dam site of the Columbia Basin project.

LOCAL DETAILS

SECTION AT DEEP CREEK

On the west bank of Deep Creek about half a mile above its mouth, at a locality that is shown in Plate III, *A*, and that has yielded a large part of the collection of fossil leaves described by Mr. Knowlton, the shale is exposed as follows:

Section on Deep Creek half a mile above its mouth

	Feet
Sand, rusty red; contains quartz pebbles and flakes of white mica	15
Shale or clay, thin bedded, lead-gray, with a few rusty-red layers. Contains abundant fossil leaves. At bottom a thin layer with fragments of wood partly changed to lignite	15
Shale, massive, bluish gray	20
Clay, containing fragments of tree stumps and stems that are partly altered to lignite	2
Bottom not exposed.	

As determined by aneroid the altitude at the base of this exposure is 1,650 feet. Above the rusty red sand at the top are basalt cliffs and talus-covered slopes rising 600 feet or more to the summit of the plateau. The beds appear to be horizontal.

SECTIONS WEST OF LATAH CREEK IN SPOKANE

Several cuts along the Spokane, Portland & Seattle and Chicago, Milwaukee & St. Paul railways in the city of Spokane west of Latah Creek expose the fossil-bearing shale. About three-quarters of a mile south of the Sunset Highway bridge over Latah Creek are cuts near each other on these two railways, which for convenience will be referred to as S., P. & S. cut No.1 and Milwaukee cut No. 1. The following section was measured in S., P. & S. cut No. 1 at an altitude of about 1,950 feet above the sea:

Section in cut of Spokane, Portland & Seattle Railway in Spokane

	Feet
Surface mantle containing large masses of basalt	6
1. Sand, white to red, moderately fine, composed of rather sharp grains of quartz, feldspar, and other minerals	5
2. Shale; rusty yellow, yields fossil leaves	10
3. Hardened clay; massive, light gray	12
Bottom not exposed.	

Bed 1 is cleanly washed stream sand that fills a channel eroded in the other layers. Many of the plant remains described by Mr. Knowlton were obtained from bed 2. There is no break between beds 2 and 3, and despite the erosional unconformity beneath bed 1 all are considered as belonging to the same series. Apparently the two lower beds were deposited in a pond or other low place so as to form a mud flat across which a gently flowing stream later spread the sand of bed 1. In places in this and some of the other cuts, as mentioned farther on, dikes and sills have intruded the beds, causing them to dip at moderate angles. Away from these disturbing features the beds appear to be horizontal and undeformed.

On the slope directly above this cut, along a road that passes through a subway on the abandoned electric-railroad grade, yellowish-gray clay and layers of cross-bedded sand are exposed. These beds are similar in composition and appearance to those in the railway cut and are regarded as belonging to the same series. They are overlain by the lowermost of the basalt flows known as the "rim rock," described on page 11, the base of which is at an altitude of about 2,250 feet.

Between the two exposures the slope is covered and the underlying formations are concealed by a rather thick mantle containing fragments and scattered large masses of basalt that apparently are the weathered remnants of later flows. Presumably the shale formation is continuous beneath this mantle; if so, its total thickness from the floor of the railway cut to the base of the "rim rock," exclusive of a 50-foot sill, is about 250 feet.

South of S., P. & S. cut No. 1 other cuts on both this railway and the Chicago, Milwaukee & St. Paul Railway expose the shale at successively higher altitudes up to about 2,050 feet, the highest being at a distance of 2 miles in the third cut to the south on the Spokane, Portland & Seattle Railway. Here 20 feet or more of light-gray shale that yields abundant plant remains is exposed.

At the contact with the intrusive dikes and sills the shale commonly appears darkened, but in places it is nearly white and baked almost to the consistency of porcelain. In Milwaukee cut No. 1 a mass of shale nearly surrounded by the intrusive rock (Pl. IV, *B*) shows a peculiar jointing that causes it to separate into slender curved columns, the size of a pencil or smaller, radially arranged about the centers of ordinary joint blocks a foot or less in size.

On the front of the spur between Latah and Lake creeks half a mile east of a cut on the Spokane, Portland & Seattle Railway a sand pit shows the following:

Section in sand pit of H. Feise, south of Spokane

	Feet
Talus composed chiefly of basalt fragments	10
Clay, massive, yellowish gray	5
Clay, sandy, micaceous, dull gray, indistinctly bedded; fragmentary plant remains near top	10
Sand, cross-bedded, medium-sized grains, cleanly washed, composed chiefly of quartz and feldspar grains and flakes of mica	20

The cross-bedding in the 20-foot layer inclines northwestward, as if the sand had been deposited by a stream flowing in that direction. The altitude at the base of the exposure is about 2,100 feet. A second sand about 20 feet lower has been uncovered in a small pit below which is a spring that is obviously fed by water stored in the two sand beds. The slope below is covered by soil and terrace gravel to an altitude of about 1,980 feet, and at that level a sill crops out that at the Latah Creek dam site, about a quarter of a mile away, has a thickness of more than 250 feet.

OTHER EXPOSURES

A particularly valuable part of the fossil collection came from a well on the Edwards ranch, about 2 miles northeast of Coeur d'Alene, Idaho. When this place was visited by Mr. Pardee early in July, 1923, no exposures of the fossiliferous beds were to be seen. The well is on a bench on the south slope of Stanley Hill, at an altitude of 2,400 feet. It is said to be 43 feet deep, and the plant remains were found near the bottom. Remnants of basalt flows that appear to overlie the shale crop out near by, and granite and schist that form the bedrock are exposed a little farther away. The matrix of the specimens from this well is of a dull-gray color, resembling that from most of the other fossil localities, but an approximate analysis shows it to contain less silica and more iron and alumina than the average.

At Thirteenth Avenue and Perry Street, in the southeastern part of Spokane, thin-bedded soft sediments that range from clay to fine sandstone are exposed to a thickness of 8 feet. The beds are gray, dip about 4° N., contain grains of quartz and flakes of white mica, and are stained rusty red on bedding planes and joints. Fossil leaves are present but not abundant or well preserved. The altitude is about 2,050 feet.

Very light-colored beds that contain abundant fossil leaves and are composed of clay, fine quartz sand, and white mica crop out at an altitude of about 2,100 feet in a ravine at the Schuele ranch, on the slope south of Fivemile Prairie, and in the cuts of the new county road on the north slope of the same "prairie," where fragmentary plant remains were found. The beds are about horizontal and are overlain by basalt, but their base is not exposed. A deposit of similar clay described by Shedd[5] occurs on the farm of W. G. Lake, 6 miles north of Spokane.

In a gulch on the slope southeast of Fivemile Prairie, about 1½ miles east of the Schuele ranch locality, 40 feet of shale that contains leaf-bearing layers is exposed. It shows the dull-gray shades and other features common to the shale elsewhere. The altitude at the base of the exposure is 2,120 feet. Slopes above and below are covered with loose fragments of basalt and soil. A flow in place corresponding to the "rim rock" crops out at 2,240 feet.

Somer's clay pits, about 2 miles south of Vera, expose 20 or 30 feet of compact micaceous white, yellow, and red clay in nearly horizontal beds that contain fossil plant remains. The clay lies upon rocks of the granite-schist group and occurs at an altitude of about 2,100 feet. The basalt cover has been stripped away by erosion, and the beds are now overlain by a thin cover of valley gravel.

Specimens obtained at Mica, Wash., are said to have come from a well at an altitude of 2,450 feet. They consist of brownish-gray clay or shale that is noticeably light in weight. The microscope shows it to be composed largely of very small cylinders and other hollow forms that are the siliceous skeletons of the minute water plants known as diatoms, described by Mr. Mann on pages 51–55. In addition the shale contains fine grains of quartz, mica, and other minerals derived from the granite and schist of the adjoining hills. Evidently the deposit was formed in a pond or marsh. It may be classified as impure diatomaceous earth and also as brick clay, but it is of different origin from the residual clays at Mica and Freeman, near by, which have been described by Shedd.[6] Evidently this deposit rests upon rocks of the granite-schist group.

Along the road up Biglow Gulch about 2 miles northeast of Hillyard the shale is exposed at an altitude of 2,200 feet. It lies upon granite and beneath a basalt flow at 2,300 feet corresponding to the "rim rock."

In Indian Canyon, above the falls, is a small exposure of fossiliferous shale at an altitude of 2,200 feet, just above the outcrop of a basalt flow. The field relations suggest that the shale lies upon the flow, which, if this is true, should be correlated with the upper one of the two flows encountered in the Hazelwood well (p. 10). However, the evidence is not decisive, and the basalt may belong to the "valley" flows and rest unconformably on the shale.

Sediments that doubtless are equivalent to the fossil-bearing beds described above are penetrated by several drilled wells—the Hazelwood well, 7 miles west of Spokane; the Hinch well, 18 miles southeast of Spokane; and the Davenport Hotel and Latah-Texas wells, in the city. The information derived from these wells is given on pages 8–9.

Above Medimont in the valley of Coeur d'Alene River, about 35 miles east-southeast of Spokane, are fine white and variegated sediments described by Hershey[7] as having accumulated in a lake caused by a dam formed of basalt. Apparently the basalt referred to is a remnant of the last or highest flow of Columbia Plateau. No fossils are reported from these beds.

DEFINITION

From the foregoing descriptions it appears certain that, except for some later intrusive rocks, the slope west of Latah Creek from the railway cuts to the

[5] Shedd, Solon, The clays of the State of Washington, their geology, mineralogy, and technology, pp. 172–174, Washington State College, 1910.

[6] Shedd, Solon, op. cit., pp. 181–194.

[7] Hershey, O. H., Geol. Soc. America Bull., vol. 23, p. 529, 1912.

"rim rock" is underlain by the fossil-bearing shale and associated beds, which aggregate at least 250 feet in thickness. Although there is no continuous exposure of such a thickness, the different places at which horizontal beds are shown at successively higher levels are comprised within so small an area that there is little room for doubt that all the exposures are parts of a continuous formation.

Inspection of the several "prairies" north and south of Spokane reveals similar relations. Each of these pleateau remnants has a cap or "rim rock" at an altitude of about 2,400 feet. Below the "rim rock" there are smooth soil-covered slopes, mostly in cultivation, as illustrated in Plate II, *A* and *B*. These smooth slopes are underlain by the clay beds, as shown by the clayey texture of the soil, by the presence of flakes of limonite characteristic of the weathered surface of the beds, and by scattered exposures in wells and road cuts.

In these localities the beds lie unconformably upon the rocks of the granite-schist group. They consist chiefly of fine sediments. Their fossils, as described farther on, indicate that they are all of the same age; and therefore all are regarded as parts of the same formation, for which the name Latah is proposed. The Latah formation, consequently, may be defined as consisting chiefly of clay and shale with some beds of sand and gravel and one or more beds that contain sufficient quantities of diatom skeletons to be classed as an impure diatomaceous earth. Many of the shale beds appear to be composed largely of very fine volcanic ash. The shale generally contains plant remains, which, as described by Mr. Knowlton in the following paper, are of middle or lower Miocene age. The formation is at least 250 feet thick in the area of typical exposure on the slope west of Latah Creek, and its range in thickness in the Spokane-Coeur d'Alene area is from 1,500 feet to the vanishing point. In the Spokane area, so far as known, it rests everywhere upon the granite-schist group, and apparently it is or was at one time covered everywhere by the lava flows composing the "rim rock." Formerly it extended continuously over the area from the Silver Hill-Cheney ridge north and east to the mountains, except for the "islands" or "steptoes" of crystalline rock, many of which were not covered even by the highest lava flow. South and west of the ridge the extent of the formation is not definitely known and the upper beds are surely absent. (See p. 10.)

STRUCTURE

Where exposed by the railway cuts west of Latah Creek the shale of the Latah formation has been deformed by intrusive bodies of igneous rock. A sill 50 feet or more thick, particularly well shown in S., P. & S. cut No. 1 and Milwaukee cut No. 1 has forced its way along a bedding plane, lifting and tilting the overlying shale. In places the intrusive rock takes the form of dikes that break across the beds and displace them slightly. This deformation, however, is confined to the vicinity of the intrusive bodies. In Biglow Gulch northeast of Hillyard and at Thirteenth Avenue and Perry Street and on Thor Street in Spokane the shale dips 4°–10° N. Whether this attitude is the result of an intrusive igneous body is not shown, but there is no reason to think it may be due to any other cause. Elsewhere from Deep Creek to Coeur d'Alene and from Duncan to Milan the beds of shale, wherever they can be seen, are horizontal.

ORIGIN

Before the Latah formation was deposited and the lava of the Columbia Plateau was extruded the rocks of the granite-schist group formed the surface in this area, the topography of which was apparently even more rough than the mountainous lands north and east of the plateau are at present. The section along the northern border of the plateau made by Spokane and Columbia rivers shows the relief of the old surface to be as much as 1,600 feet. At Spokane, as indicated by the Latah-Texas well (p. 8), there is a submerged valley at least 1,000 feet deeper than the present one. The 1,100 feet of lava and sediments penetrated by the Hazelwood well (p. 10) probably fill the ancient prolongation of this old valley. At the south of this buried valley is a ridge whose summits project through the lava to form the chain of hills that extends from Silver Hill by way of Marshall and Cheney to Medical Lake and, as suggested by the smaller but otherwise similar hills of granite northwest of Deep Creek, probably continues 20 or 30 miles farther northwest. (See Pl. I.) At Duncan the present valley of Latah Creek crosses this ridge, cutting deeply into the granite and schist.

Most persons familiar with the Spokane area have been of the opinion that the fossil-bearing sediments described herein accumulated because the drainage was obstructed by lava flows advancing upon a mountainous region. Under this condition sediments brought down from the lands to the north and east would be deposited at the borders of the flows. Successive flows would result in a succession of sedimentary deposits, each one farther east or north and at a higher level than its predecessors. Thus it would be supposed, for example, that after the beds at Deep Creek were laid down a lava flow extended eastward beyond that point, causing a new pond in which the beds at S., P. & S. cut No. 1 accumulated. After this process was repeated there would be a succession of lava flows alternating with layers of sediment partly extending in front of them and partly interbedded with them. The information recently obtained in this area by the writers, however, makes necessary a modification of that idea so far as details are concerned. North of the buried ridge represented by the Cheney Hills no interbedded lava flows were found, except possibly at Indian Canyon (p. 6), and such flows are known only in the Hazelwood well, mentioned on page 10. The sediments appear to belong to a single formation that was completely deposited before any of the flows near Spokane and their related sills and dikes came to place. They accumulated in a basin that extended from the buried ridge north and northeast to the limits of the area surveyed. As shown by the character of the sediments, this basin was at times occupied by ponds and at times became drained so that streams flowed across its floor. Leaves and wood of the forests growing on the neighboring lands and on the alluvial plains of the basin fell into the streams and, on being buried in the mud and sand, were preserved.

The materials that form the leaf-bearing Latah formation were derived from explosive volcanoes and from the erosion of the granite gneiss of the mountains adjacent on the east. The finer beds are composed largely of volcanic ash of an andesitic type. The coarser beds are generally composed of grains of quartz and feldspar, but in some localities black and gray quartzite makes up about half of the grains, as shown by a study of samples from the drill holes at the Latah Creek dam site. At the Dry Creek dam site, near Milan, however, no quartzite was found, and this fact was used to distinguish the Latah gravel from the overlying flood-plain deposits. No basalt pebbles were found in any material from the Latah formation.

The character of the material and the type of rock composing the larger grains indicate that the formation as a whole was derived from the erosion of the region to the east but that local streams draining areas with slightly different bedrock carried on the work of deposition in different places. It appears also that the formation was deposited in a basin at the foot of the mountains and in a period preceding that of any of the basalt flows now exposed on the surface in the Spokane region. Some beds were doubtless deposited in still water, as shown by their fine grain and delicate lamination. The leaves that are so beautifully preserved in many beds are generally quite perfect and lie parallel to the lamination of the shale. They were evidently floated into place rapidly but gently. Such beds must have been deposited in quiet ponded water and seem to indicate the presence of lakes. Other beds, however, contain the macerated remains of vegetation such as now accumulates in the bottoms of swamps. The sand and fine gravel were deposited by currents, as shown by their cross-bedding, and doubtless represent the channels of streams. The Latah formation seems therefore to have been deposited in a broad plain of alluviation containing lakes and swamps, over which the streams from the mountains on the east found their way through sluggish channels toward the west.

The cause of this ponding of the streams might, so far as evidence from the fossil-bearing beds is concerned, be attributed either to local subsidence or to the building of a dam across the lower courses of the streams by the earlier and lower members of the basalt series that occupies the basin to the west. The idea of subsidence during deposition is unsupported by any evidence, but ponding of the drainage by lava flows is a hypothesis based on a number of ascertained facts and logical inferences. The sediments of the Latah formation are earlier than any of the basalt flows that crop out in the immediate neighborhood of Spokane, except possibly the flow at Indian Canyon. (See p. 6.) On the other hand, the data derived from wells presented on page 10 indicate interbedding of the clay shale with flows west of Spokane. This seeming discrepancy has already been explained as due to the presence of the submerged ridge now represented by the Cheney Hills and similar knobs, which acted as a barrier during the time of extrusion of the basalts of the plateau to the west and held back the advancing lava. Thus while flow after flow desolated the general region of the Columbia Plateau, the Spokane area, owing to the protection afforded by the Silver Hill-Cheney ridge, was the scene of uninterrupted and quiet sedimentation until it too was finally overwhelmed by the flows of the "rim rock."

Though the Spokane area was free of lava flows, showers of volcanic dust were sufficiently frequent to supply much of the material composing the shale. Mr. Knowlton, as set forth in the succeeding paper, believes that the Latah formation is of middle or lower Miocene age and that it is to be correlated with the Ellensburg and Mascall formations. These formations consist in part of tuff beds. Volcanic débris in the Latah formation is to be expected, but the Spokane area doubtless lies at a great distance from the centers of eruption, for all the material attributable to volcanic explosions so far found is of microscopic size.

THICKNESS

As shown in the geologic cross section of Figure 2, the top of the Latah formation in the Latah Creek valley is at an altitude of 2,250 feet, and the floor of the valley is at 1,750 feet. These figures indicate a thickness, including the intruded sills, of 500 feet. The Latah-Texas well, however, according to the drill samples shown to Mr. Bryan, after passing through the gravel of the flood plain and a thin layer of basalt, penetrated gray shale, dirty gravel, sand, and gravel, similar to material found elsewhere in the Latah formation, for 1,089 feet before entering the underlying granite gneiss. The total thickness of the Latah in this locality must therefore be from 1,400 to 1,500 feet.

In the city of Spokane the well in the Davenport Hotel, after passing through 430 feet of gravel and basalt, entered shale and sand and ended in gravel at a depth of 668 feet. (See fig. 3.) The sediments found in this well below the basalt are correlated with the shale that has been exposed in excavation at several localities in the north slope of Manito Prairie up to the base of the overlying lava, at an altitude of 2,150 feet, or about 250 feet above the Davenport Hotel. A minimum thickness of 918 feet is thus indicated beneath the central part of the city of Spokane.

EXTENT

The distribution of the Latah formation is shown on the accompanying map (Pl. I). In many places on the slopes of the "prairies" it is concealed by talus, glacial till, and terrace gravel. In the Latah Creek valley the only good exposures are in the railway cuts previously described. In general a deep mantle of glacial gravel conceals the slopes, but an unusually detailed search for outcrops of the shale and the intruded sills, together with the results of drilling at

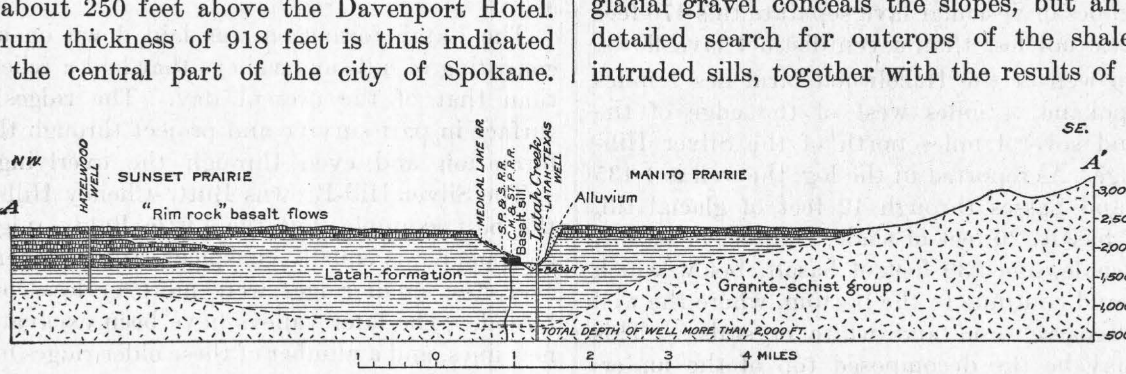


FIGURE 2.—Geologic cross section from Sunset Prairie to ridge east of Manito Prairie, Wash., along line *A-A'*, Plate I

Between the mouth of Deep Creek, 8 miles northwest of Spokane, and Mica, about 12 miles southeast of the city, the vertical range of exposures, as already mentioned on page 4, is about 800 feet. Several wells, about which conflicting stories are current and much misinformation exists, were drilled in a vain search for oil near the intersection of Twenty-ninth Avenue and Southeast Boulevard. Information obtained by Mr. Henry Fair during the period of drilling indicates that one well reached a depth of 1,400 feet and penetrated 264 feet of basalt and 286 feet of clay and shale of the Latah formation before entering

the Latah Creek dam site, permits the mapping of the formation in this valley with entire confidence. In the valleys of Spokane and Little Spokane rivers the underlying formations are masked by glacial gravel, but doubtless the Latah formation is close to the surface in a number of places, where it may be later uncovered by excavations, as it has been in the clay pits south of Vera.

The Latah formation extends up Latah Creek about 10 miles to Duncan, where a ridge of granite and other rocks is exposed by the erosion of the valley. This ridge, as described on page 10, extends from Silver

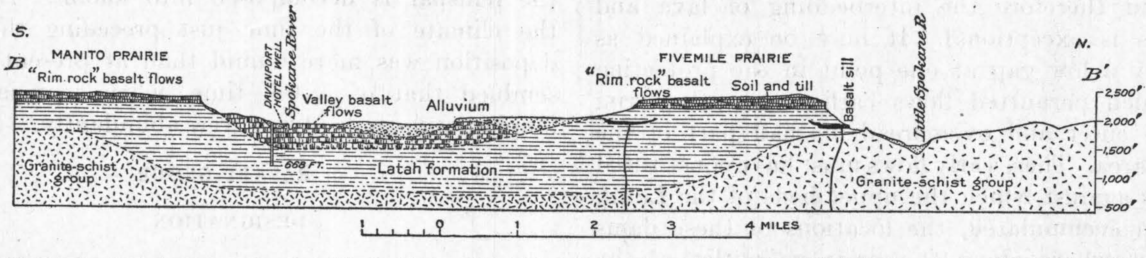


FIGURE 3.—Geologic cross section from Manito Priaire though Fivemile Prairie to ridge north of Little Spokane River, Wash., along line *B-B'*, Plate I

the underlying rocks. This well is on Manito Prairie at a point about 400 feet higher than the collar of the Davenport Hotel well. It shows that the pre-Latah surface rises rapidly toward the eastern hills (fig. 3), a condition also indicated by other field evidence.

It is evident from the foregoing considerations that the Latah formation attains a considerable thickness, but in Pleasant Prairie, Greenbluff Prairie, and other localities the formation decreases in thickness to the vanishing point in the direction of the hills that existed at the time of deposition, and there the overlying basalt flows rest directly on the granite gneiss.

Hill, east of Latah Creek, west through Browns Butte and the hills north of Cheney to a point beyond Medical Lake. (See Pl. I.) South of the ridge Latah Creek has cut its valley wholly in basalt, of which nearly 500 feet is exposed (Pl. III, *B*). The Hinch well, near Mount Hope, east of the creek, in the SW. ¼ sec. 14, T. 22 N., R. 44 E., penetrates 53 feet of soil, 271 feet of basalt, 20 feet of shale, 572 feet of basalt with streaks of clay, sand, and gravel, and 530 feet of shale and sand. Entirely different conditions of deposition from those near Spokane are indicated by this log. The overlying lavas are 843 feet thick and are divided into upper and lower portions by 20 feet of shale. The 530 feet of shale and sand at the bottom of the well, if considered as equivalent to the Latah, must represent only the lower part.

The well of the State Normal School at Cheney is also south of the ridge. Below 32 feet of gravel and clay, doubtless of Pleistocene age, the well penetrates basalt for 470 feet. Clay beds from 6 to 12 inches thick and zones of vesicular lava separate this 470 feet of basalt into not less than seven distinct lava flows.

The deep well at the Hazelwood farm lies 7 miles west of Spokane, 4 miles west of the edge of the plateau, and several miles north of the Silver Hill-Cheney ridge. As reported in the log, the well is 1,135 feet deep and passes through 12 feet of glacial till, 159 feet of basalt, 20 feet of shale, 200 feet of basalt, 67 feet of shale, and 230 feet of basalt, below which shale and sand continue to the bottom, where the well ended in "coarse sand and white crystals." This material may be the decomposed top of the underlying granite gneiss. So little information is given by the log that the two thick beds of basalt below the "rim rock" may be interpreted either as flows or as sills. However, a shallow well in the same locality has a more perfect log from which it is evident that the first of the two lower basalts consists of alternating hard and soft layers. The description by the driller is similar to that of the upper or "rim rock" basalt. If the log of the shallower well is used to interpret the log of the deeper, it appears that 4 miles west of the edge of the plateau the Latah formation is interbedded with lava flows, and this interpretation has been used in drawing the cross section of Figure 2. This locality is on the Spokane side of the buried ridge, and therefore the interbedding of lava and sediments is exceptional. It may be explained as caused by a low gap at one point in the protecting ridge which permitted flows earlier than the "rim rock" to enter and overspread a small part of the Spokane area. These early flows must have constituted the dams against which the upper beds of the Latah formation accumulated, the locations of these dams being somewhere along the drainage outlet of the Spokane area at that time and beyond the limits of the region here considered.

Farther west the lavas are more continuous and there is less intervening shale. At Palouse Falls, 70 miles southwest of Spokane, a well 951 feet deep, as reported by the driller, passed through 59 feet of soil, sand, and gravel and then through 892 feet of basalt in which beds of shale spaced at uneven distances and ranging from 5 to 16 feet in thickness were found. In the Columbia Basin, west of the buried ridge, 1,200 to 1,500 feet of basalt without intervening shale is exposed. The transition between the geologic sections in the Spokane and Basin areas is partly revealed in the logs of wells at Medical Lake and Davenport. At Medical Lake, 13 miles southwest of Spokane, only 14 feet of shale can be certainly identified in the upper 465 feet of the well for which a log is available. A well 503 feet deep at Davenport, 33 miles west of Spokane, after passing through gravel and clay for 24 feet, went into rock that, from the log, is evidently a series of basalt flows.

PRE-LATAH SURFACE

The Latah formation was laid down on a surface consisting of hills and valleys that had a relief greater than that of the present day. The ridges of that surface in part survive and project through the Latah formation and even through the overlying basalt.

The Silver Hill-Browns Butte-Cheney Hills ridge is the best example, but the Little Baldy ridge, north of Spokane, is equally conspicuous. In general, however, the small ridges were more or less completely buried. The later valleys have been excavated along new lines, and a number of these older ridges have been exposed (Pl. II, *A*). Where the present valleys cross these ridges they are relatively narrow and steep. At the Deep Creek and Deadman Creek dam sites, north of Spokane, pre-Latah ridges are exposed. Other ridges are entirely buried beneath the Latah and the overlying basalt.

The surface on which the Latah formation was laid down had been subjected to weathering for a considerable time. As shown in outcrops and more particularly in the drill holes that pass through the Latah formation, put down on Dry Creek and Deadman Creek in the course of the Columbia Basin investigation, the granite gneiss is much decomposed on the contact. The rock is soft and shattered, and the feldspar is decomposed into kaolin. Evidently the climate of the time just preceding the Latah deposition was more humid than at present and resembled that of Latah time, when sequoias, oaks, maples, and similar trees grew abundantly.

BASALT GROUP

DESIGNATION

Under the older usage all the basalts that underlie the great plateaus of the Columbia region were known collectively as the Columbia River basalt. This term, as defined by Russell,[8] included all of the series, from 1,200 to 1,500 feet in thickness, that occupies the central region of Columbia Basin, as well as several groups of flows in the foothills of the Cascade Mountains from Yakima to Wenatchee. It was shown by Smith,[9] however, that in the region northwest of Ellensburg Eocene sandstone and shale are interbedded with the lower flows. The Columbia River basalt obviously required subdivision; the name

[8] Russell, I. C., A geological reconnaissance in central Washington: U. S. Geol. Survey Bull. 108, pp. 20-22, 1893.
[9] Smith, G. O., op. cit., pp. 1-4.

Columbia, moreover, was preoccupied. The basalt flows that overlie the late Eocene beds and were overlain by the Ellensburg formation, of Miocene age, were accordingly named by Smith the Yakima basalt. Since that time all the basalts of the Columbia Plateau have generally been correlated with the Yakima basalt, of supposed Miocene age. As pointed out on page 12 the recent studies of the Latah formation cause this correlation to be modified so far as the Spokane area is concerned. Doubt has also been cast upon the general correlation in the neighborhood of Pasco by the work of Merriam and Buwalda.[10] It therefore seems best at present to consider the basalts under a general term, and to subdivide them into local groups without attempting to assign formation names.

FLOWS OF THE "RIM ROCK"

In the neighborhood of Spokane the Columbia Plateau is underlain by two or perhaps three basalt flows that aggregate at least 200 feet in thickness. These flows rest upon the horizontal upper surface of the Latah formation at an altitude of about 2,200 feet. Within the limits of their thickness they submerge the older rocks that project above this level. As a rule the outcropping edges of these flows form the prominent dark vertical cliffs and crags that surmount the slopes leading up to the plateau. The conspicuous cliff known as the "rim rock," which forms the edge of the plateau southwest of Fort Wright, though it does not measure their entire thickness, fairly represents them and affords them a convenient name.

The "rim rock" flows show a pronounced vertical jointing that causes them to separate readily into the five or six sided columns that decorate nearly every cliff-like exposure. Particularly fine columns 2 or 3 feet in diameter are to be seen in the cut on the Sunset Highway just west of Dead Man's Curve (Pl. IV, *B*) and in the quarry of the Washington Water Power Co. near by. Within the area immediately adjacent to Spokane this jointing appears to be more characteristic of the "rim rock" flows than of the "valley" flows described farther on and thus in a measure serves to distinguish them. In a few localities shattered material with large "pillows" occurs, but rock of this type is not so abundant as in the "valley" flows (p. 14).

Vesicles, or gas holes, which are common at the top and bottom of the flows, are in natural exposures empty or contain a little iron rust or calcium carbonate. In a road cut and quarry near the corner of Twenty-ninth Avenue and Southwest Boulevard, Spokane, aragonite in slender clear crystals and sphaerosiderite occur in the vesicles. In a quarry on the southeast face of Fivemile Prairie the vesicles are large and shaped much like a collapsed tennis ball. There sphaerosiderite and calcite occur. Limonite replacing sphaerosiderite is common in most localities. It has been found in association with green and brown opal 10 miles south of Spokane on the Palouse Highway, on Pleasant Prairie, and at the north edge of Fivemile Prairie.

Representative specimens of the "rim rock" flows from four different localities—the southwest edge of Fivemile Prairie, the plateau half a mile west of Fort Wright, Biglow Gulch east of Hillyard, and the quarry of the Washington Water Power Co. south of Dead Man's Curve on the Sunset Highway—are all basalts consisting essentially of plagioclase feldspar and pyroxene with subordinate olivine and more or less glass. As determined by F. C. Calkins,

> Most of these contain at least a few small roundish blowholes, and all contain small irregular pores from the walls of which crystals of feldspar project. All appear well crystallized. Under the microscope it is seen that all contain a moderate amount of olivine. The augite forms interstitial granules or larger individuals inclosing or molded upon the laths of plagioclase. A good deal of brown glass, crowded with particles of iron ore and with other microlites, is present in all specimens.

Flows correlated with those of the "rim rock" form cliffs at the same level on the opposite side of the valley, at the edges of Fivemile Prairie and the other plateau remnants along Little Spokane River, on the west side of the Latah Creek valley, and elsewhere, as shown on the geologic map (Pl. I). Before these valleys were cut the flows must have extended continuously across the area. Within the limits indicated the flows appear to be horizontal and to be confined to altitudes between 2,200 and 2,400 feet. East and southeast of Spokane, however, basalt that is apparently the same as the "rim rock" flows occurs at higher levels. Near Mica it reaches an altitude of 2,600 feet but its base is not exposed. In the neighborhood of Coeur d'Alene it occurs between the 2,300 and 2,500 foot levels. Possibly this difference in height is to be explained as a result of a later slight elevation of the earth's crust toward the southeast, an idea that is supported by the fact that in several places in the Columbia Plateau outside of the Spokane area the lava is moderately deformed.

This basalt is thought to have risen through fissures to the surface, where it spread out in the form of sheets. For the reason that no adequate vents are known outside the borders of the plateau, the bulk of the lava is thought to have come from fissures within its area and therefore to the south and southwest of Spokane. Presumably the dikes exposed in the railway cuts west of Latah Creek described on page 12 represent vents through which a small part of the lava composing the "rim rock" flows reached the surface. The bulk of the lava, however, must have risen through larger fissures situated farther southwest.

[10] Merriam, J. C., and Buwalda, J. P., Age of strata referred to the Ellensburg formation in the White Bluffs of the Columbia River: California Univ. Dept. Geology Bull., vol. 10, pp. 255-266, 1917.

The flows of "rim rock" lie upon the beds of the Latah formation and show no angualr discordance with them. The contact can be observed in only one locality, a road cut on Pleasant Prairie near the line between secs. 29 and 30, T. 24 N., R. 44 E. At this place, as shown in Plate IV, *C*, the much weathered basalt rests on a black soil zone from 2 to 4 inches thick containing lignitized twigs and other vegetable litter. Below the soil the Latah shale, easily identified by scattering and imperfect plant remains, is weathered and iron stained for 2 to 3 feet. The contact is slightly uneven but does not give any definite indication of erosion of the shale. Apparently the soft beds of the Latah formation had been exposed to erosion only long enough to produce slight irregularities in the surface and a soil zone before the lava covered them. The conclusion seems to be that the flows of the "rim rock" are but little younger than the Latah formation.

The "rim rock" flows of the Spokane area form a definite group, but a thicker series of basalt flows underlies the plateau to the south and west of this area. On the surface the "rim rock" flows appear to be continuous with the top flows of this thicker series. In the Hazelwood well the lower flows are thought to belong to the thicker series.

In the Ellensburg quadrangle, about 150 miles west-southwest of Spokane, the geologic section[11] includes, in ascending order, the Yakima basalt, Ellensburg formation, and Wenas basalt. The Yakima basalt submerges an uneven surface of older rocks and consists of many flows piled one on the top of another to a thickness of 2,000 feet or more. The overlying Ellensburg is composed of sediments having a total thickness of as much as 1,600 feet. The Wenas basalt comprises two or three flows of rather small extent that range from a few feet to 200 feet in aggregate thickness. It overlies the Yakima basalt, from which it is separated by Ellensburg sediments ranging from 84 to 135 feet in thickness. The bulk of the Ellensburg beds lie above it.

In the general vicinity of Yakima the Ellensburg formation overlies the Yakima basalt, which is generally regarded as equivalent to the bulk of the basalt of the Columbia Plateau. Likewise the Mascall overlies the main body of basalt in central Oregon, which also is regarded as a part of the basalt of the Columbia Plateau. In the Spokane area no flows were found in a position corresponding to the Yakima basalt, namely, beneath sediments corresponding to the Ellensburg, or in other words, the Latah. The "rim rock" flows, which overlie the Latah, are therefore later than the Yakima basalt. However, there is nothing to suggest that they are much later.

The area north of Spokane River and west of the valley of Little Spokane River shown on the geologic map (Pl. I) has not been examined in detail by the writers. The geology has been generalized from the excellent map of Weaver,[12] and his Camas basalt has been considered equivalent to the flows of the "rim rock." For this correlation the only evidence is that the Camas basalt of Weaver is also olivine bearing, attains similar altitudes, and consists of small patches that appear to be outliers of the Columbia Plateau.

BASALT SILLS AND DIKES

The Latah formation has been intruded by igneous rocks, as may be observed at intervals along the slope west of Latah Creek from S., P. & S. cut No. 1 and Milwaukee cut No. 1 southward and also in the slopes of several of the "prairies" north of Spokane and elsewhere.

In the railway cuts of the Latah Creek valley three dikes from 2 to 10 feet wide and several dikes merging into sills are exposed. The type of dike is shown in Plate V, *A*, the base of one of the sills in Plate V, *B*, and the end of another in Plate V, *C*. The rock in both dikes and sills is a fine-grained dense blue-gray basalt similar in hand specimen to the overlying basalt of the "rim rock." The similarity in mineral composition, particularly in the presence of olivine, as shown below, between the rock of the dikes and that of the "rim rock" flows lends support to the supposition that the dikes were feeders in the eruption of the flows. Both the dikes and the sills have a fine-grained or glassy exterior where they cooled quickly in contact with inclosing shale. The grain of the interior is fine in small bodies and becomes coarser in the central parts of large bodies. Near the contact the shale is slightly hardened and changed in color. This influence on the shale extends from 6 inches to 10 feet. Beyond this zone the shale is entirely unchanged.

Specimens representing three of these intrusive bodies exposed in the railway cuts west of Latah Creek are described by Mr. Calkins as follows:

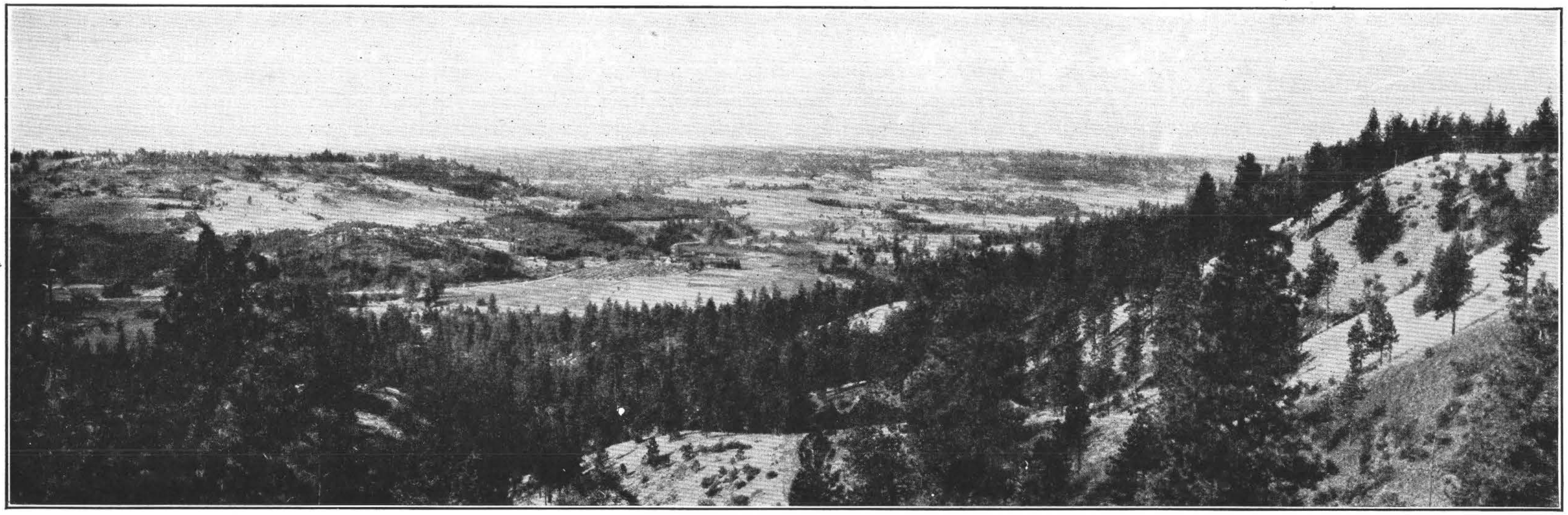
Specimens taken several feet from contacts either are quite compact or contain only minute irregular pores not readily visible without the aid of a hand lens. The textures are moderately fine and might be taken for holocrystalline. Under the microscope, however, a little residual glass is found in even the most crystalline specimen (No. 10), taken from the middle of a 40-foot sill. Except for the presence of this glass, the texture of the specimen is typically ophitic. The most abundant constituents in all are of course plagioclase and augite; and olivine, though subordinate to plagioclase and augite, is present in all the specimens having a crystalline appearance but No. 7. This specimen is further remarkable in containing uniformly scattered grains of siderite which shows no evidence of being secondary; I regard it as having been the last original constituent to form.

Two specimens from the margins of a sill and a dike have a wavy surface and a visibly glassy selvage about half an inch thick. A thin section from the selvage shows plagioclase laths as the only identifiable crystals in a cloudy glass base.

[11] Smith, G. O., op. cit.

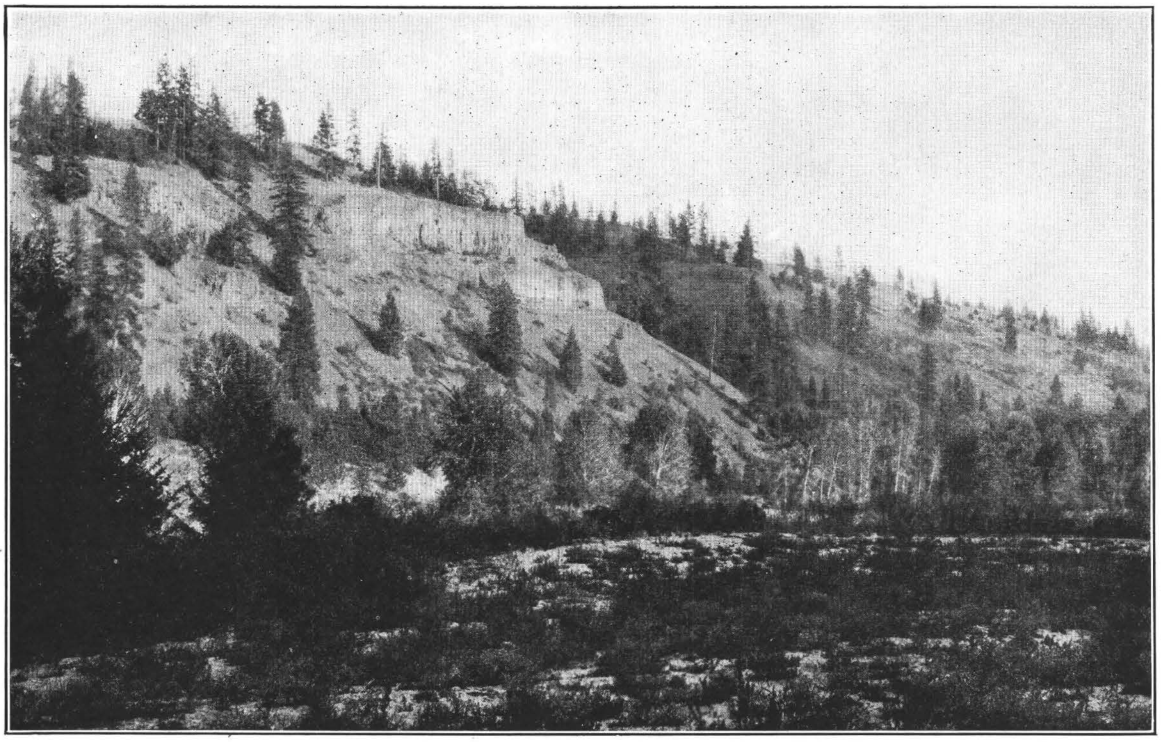
[12] Weaver, C. E., op. cit., pp. 99-101.

A. PLEASANT PRAIRIE, WASH.

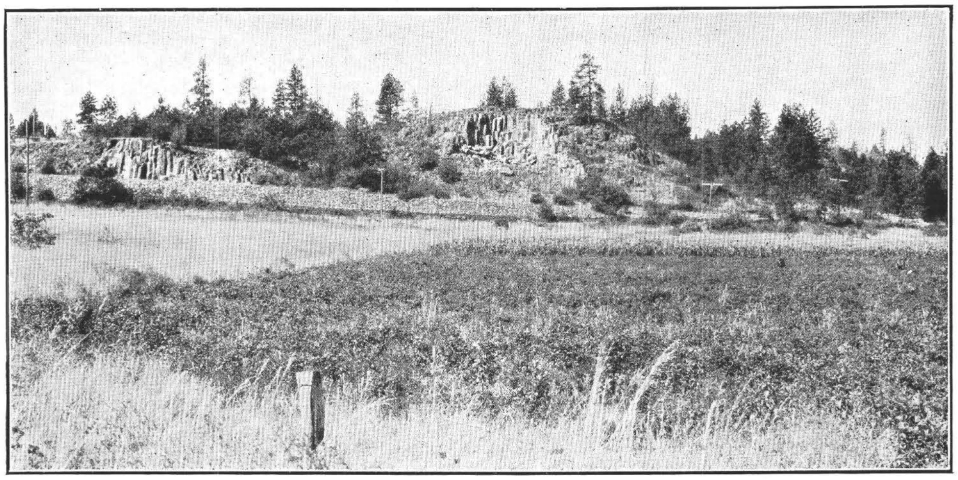


B. LATAH CREEK VALLEY AND THE COLUMBIA PLATEAU, WASH.

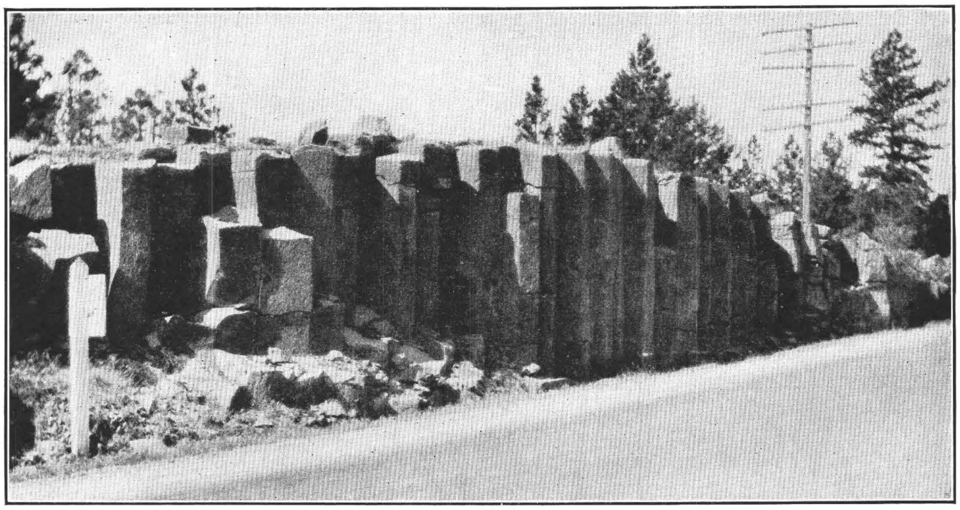
A. LATAH FORMATION AND FOSSIL LOCALITY OF DEEP CREEK CANYON, WASH.



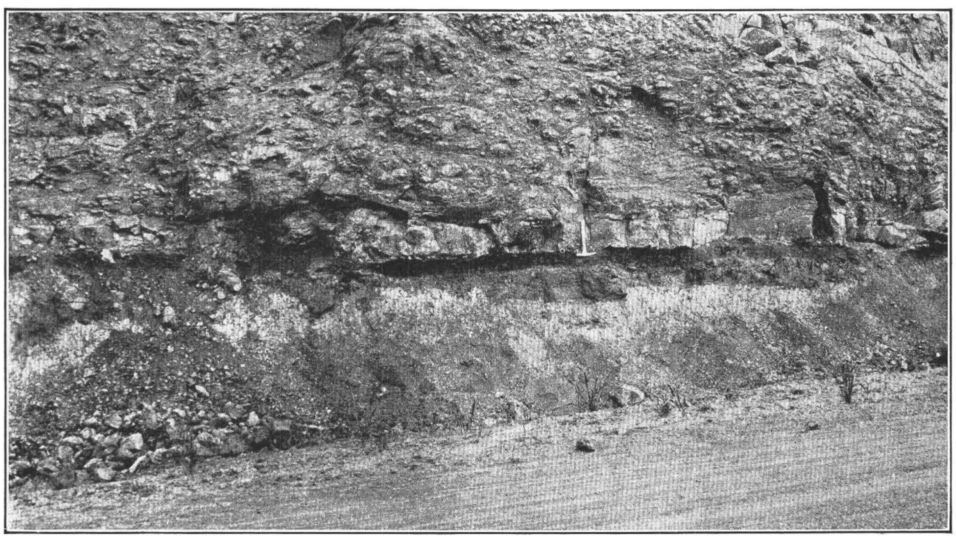
B. EAST SIDE OF LATAH CREEK VALLEY SOUTH OF DUNCAN, WASH.



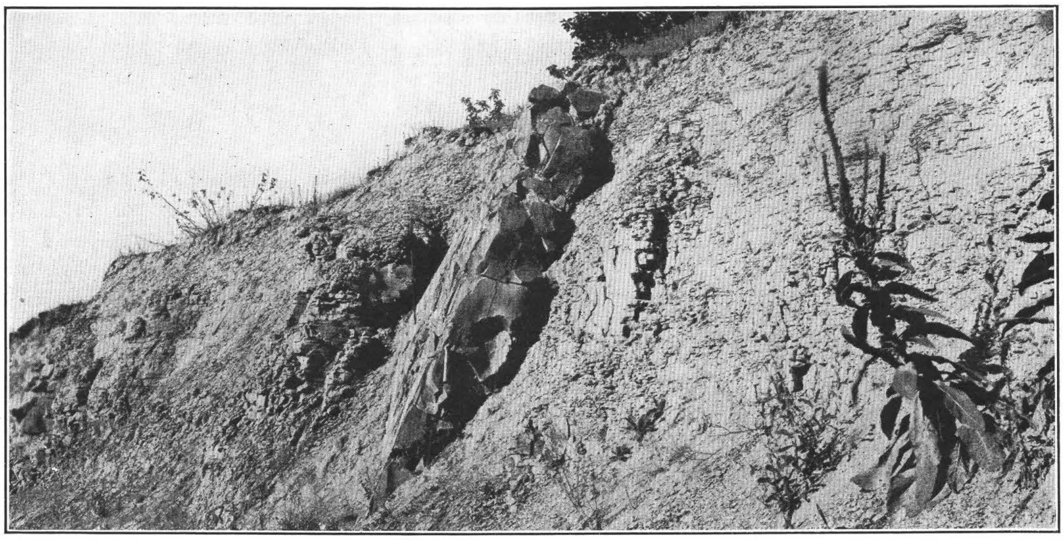
A. "RIM ROCK" FLOWS, SUNSET HIGHWAY WEST OF SPOKANE, WASH.



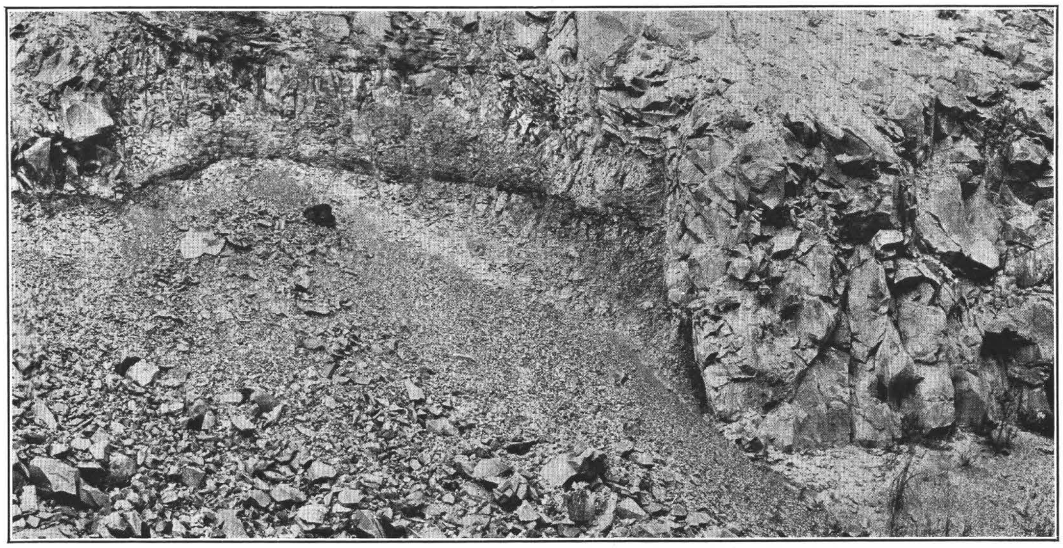
B. DETAIL OF COLUMNAR JOINTING IN CUT ON SUNSET HIGHWAY



C. CONTACT OF "RIM ROCK" FLOWS ON LATAH FORMATION ON PLEASANT PRAIRIE, WASH.

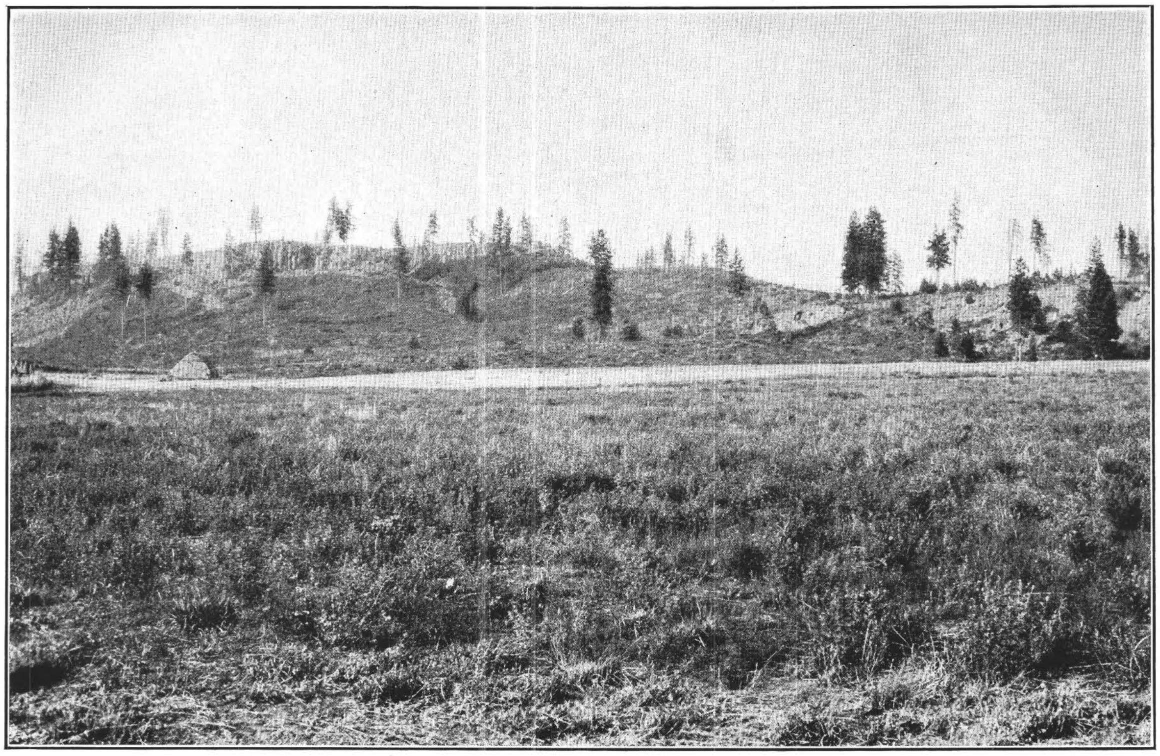


A. BASALT DIKE INTRUDED INTO SHALE, S., P. & S. CUT NO. 4, SPOKANE, WASH.

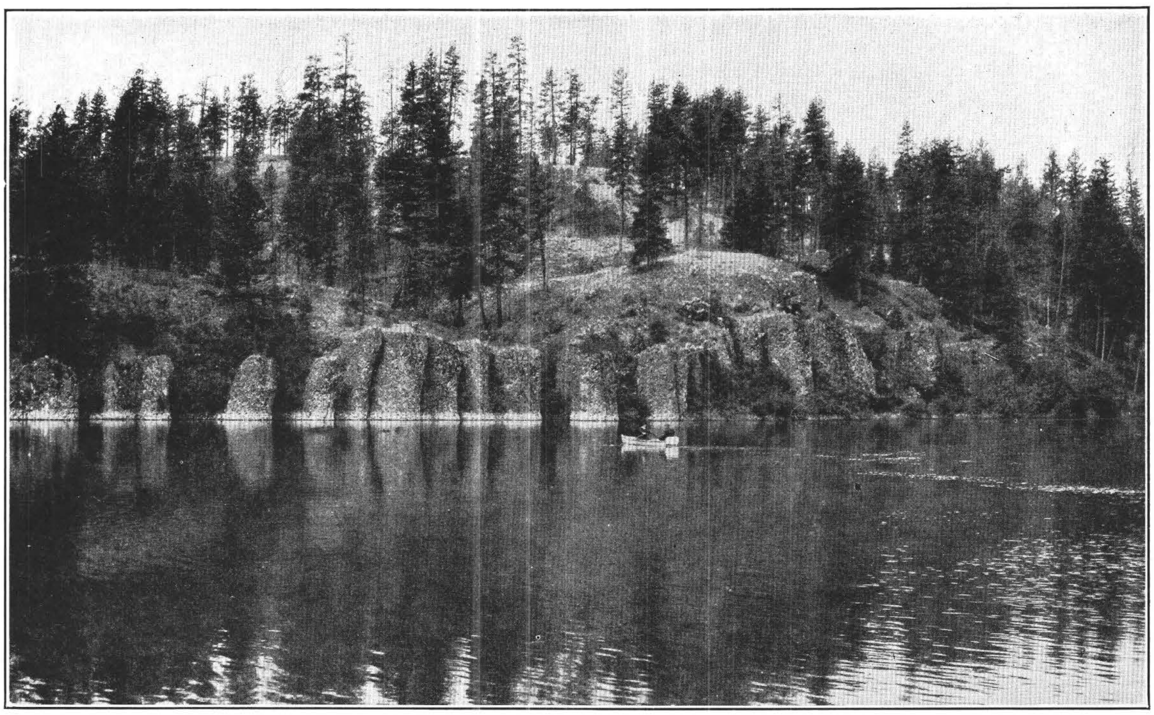


B. LOWER CONTACT OF BASALT SILL WITH SHALE, MILWAUKEE CUT NO. 1, SPOKANE, WASH.

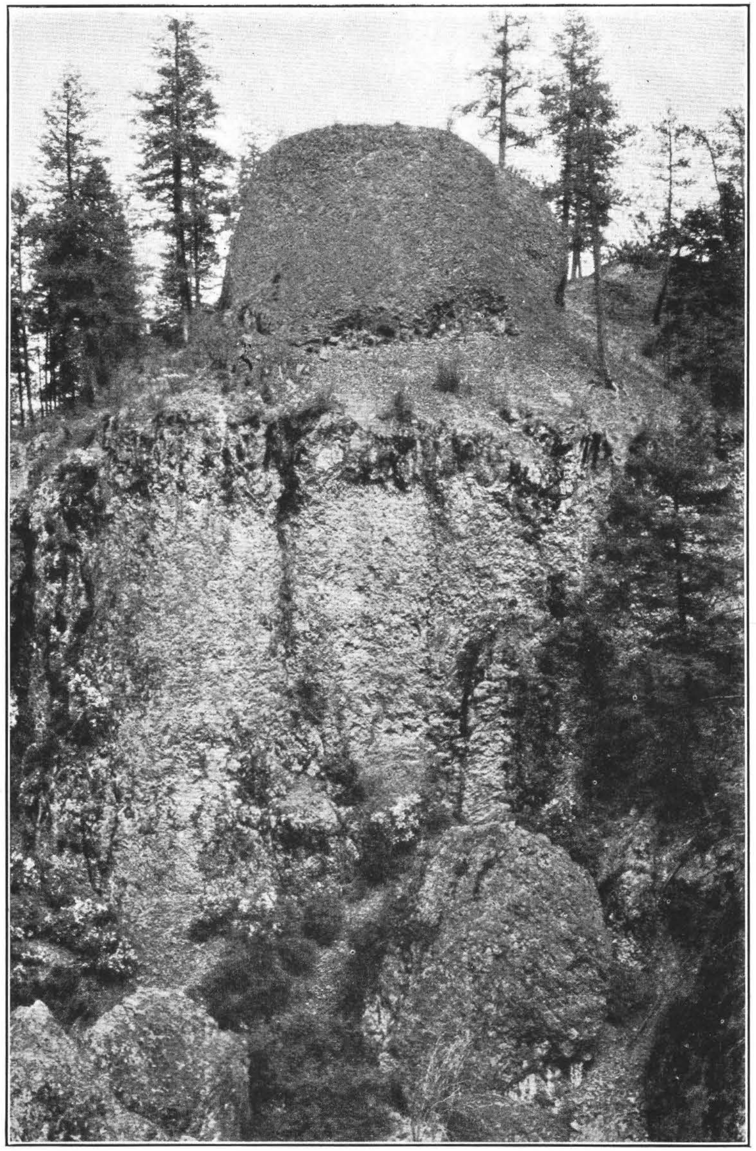
C. END OF BASALT SILL, SPOKANE, WASH.



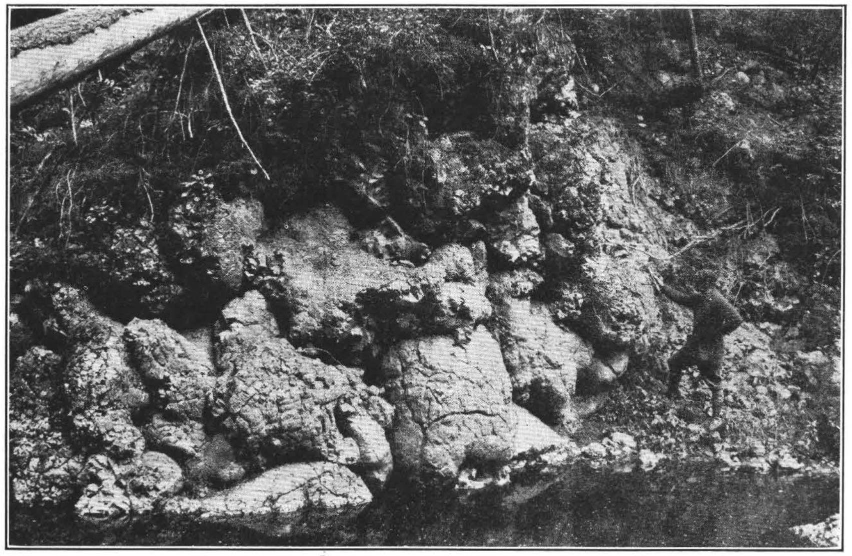
A. "THE CLIFF," NEAR MILAN, WASH



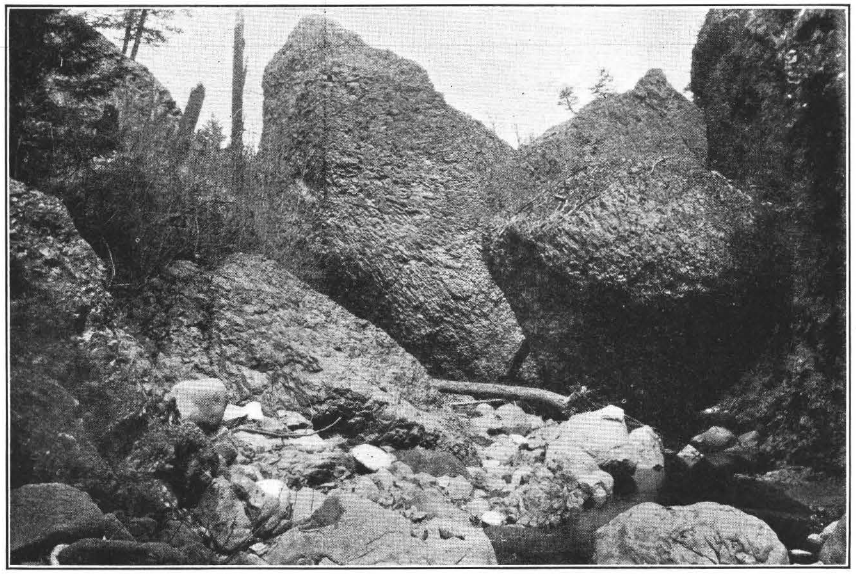
B. VALLEY FLOWS ON LEFT BANK OF SPOKANE RIVER NEAR SEVENMILE, WASH.



A. BASALT CLIFFS AT MOUTH OF CREEK



B. "PILLOW" STRUCTURE IN THE VALLEY FLOWS OF THE CANYON



C. DEVILS TOP

Photograph by William Donahue

VIEWS ON DEEP CREEK, WASH.

The dikes arose along joint planes and caused no disturbance of the shale, but the sills have wedged themselves between beds and have broken and crumpled the shale for distances of 50 to 100 feet.

In the Latah Creek valley the number of sills is large. Most of them were intruded at altitudes between 1,800 and 2,000 feet. Many are 25 to 50 feet thick and from 300 to 500 feet long. All that could be observed end abruptly. The lower sill shown in the cross section of Figure 2 is at least 100 feet thick, and it crops out along the valley for about half a mile. The sill on the west abutment of the Latah Creek dam site (Pl. II, *B*) is more than 250 feet thick, yet, as was brought out in striking fashion during drilling operations at this place, it ends abruptly on the east.

Basalt sills are common features of the slopes developed on the Latah formation in all the "prairies" north of Spokane. These sills are irregular in position, thickness, and length, and their outcrops are in many places more or less concealed by soil or glacial till. A few of the more prominent sills are represented on Plate I.

Because the sills intruded in the Latah formation lie approximately horizontal, there is some difficulty in distinguishing in the field the outcrops of such bodies from those of interbedded lava flows. The mineral composition and texture of the two, so far as can be seen by the unaided eye, are almost identical. But the sills cooled under cover and under pressure and therefore, except for the thin glassy crust, which is seldom seen except in artificial exposures, they are massive and free from scoriaceous and vesicular portions. Near the margin some sills have small scattered gas holes. The flows, however, owing to the expansion of gases expelled from the lava during cooling, have scoriaceous and vesicular layers at the top and usually similar layers at the bottom. Some of the sills have well-marked columnar jointing, the joints being tight and the columns large and regular, but as a rule jointing is not well marked in these bodies. Generally the flows show a jointing that is variable or irregular but usually open and conspicuous. The most useful criterion is perhaps the discontinuity of the sills. Interbedded flows would have more or less continuous outcrops at the same altitude for long distances. The end of a flow, moreover, is marked by a characteristic rubble or by scoriaceous material or, as in the "valley" flows described in the next section, by "pillow" structure.

FLOWS IN THE VALLEYS

The basalt flows that underlie the city of Spokane and cause Spokane Falls occur, so far as now known, only in valleys eroded in the "rim rock" flows and the Latah formation.

In the city of Spokane, along the gorge of Spokane River, and in the valleys of Latah Creek, Deep Creek, and Little Spokane River the slope below the "rim rock" exhibits cliffs and other rugged outcrops of basalt that, in one place or another, include parts of all the flows of a complete series built up from the bottom. In general the areas in which these lavas crop out are small, but on the geologic map (Pl. I) a large area is shown west of the valley of Little Spokane River near Deer Park. This area was not examined in detail. It is generally flat and has an altitude of about 2,000 feet, or about that of the most prominent glacial terrace (p. 15). Half Moon Prairie is underlain by basalt, and so also are large areas southeast of Deer Park. The cover of gravel belonging to the terrace makes mapping a long and tedious task and makes the identification of the basalt with the younger series uncertain. The inclusion of this area with the area of "valley" flows must be considered tentative.

The highest of these "valley" flows reaches an altitude a little greater than 2,100 feet. It forms the cliff at the falls in Indian Canyon and low cliffs near the head of the small valley tributary to Latah Creek north of S., P. & S. cut No. 1. Large loose masses of basalt on the slope above this cut, in Spokane at Cannon Hill and elsewhere, probably are remnants of this flow. At Ash and Fairview streets, in the northwestern part of Spokane, and at places down Spokane River there are remnants of a flow at an altitude of about 2,000 feet. At the next lower level is the thick mass of basalt composed of two or three separate flows across which Spokane River descends in the famous cataract of Spokane Falls.

The base of the "valley" flows at Spokane is located by the well at the Davenport Hotel (p. 9 and fig. 3). Farther north, however, it may be lower. If the bottom of the lava in the Davenport Hotel well is the maximum depth, the valley eroded in the "rim rock" flows and the Latah formation had a depth of at least 880 feet at Spokane. The erosion of this valley must have required considerable time. It is a measure of the difference in age of the "valley" and "rim rock" flows.

Contacts between the "valley" flows and the Latah formation have been observed by the writers in only three places. At Deep Creek, in 1922, the basalt could be observed resting against a slope covered by 5 feet of rubble and soil, which in turn rested on the shale of the Latah formation. This contact was buried as a result of the spring floods in 1923. In a cut on the Spokane, Portland & Seattle Railway in the western outskirts of Spokane, near Fort Wright, the contact of the lavas on the Latah is well exposed. The contact has irregularities of 5 to 10 feet, but the general slope is to the north and east. Much of the lava at this place is a breccia or rubble of broken material and "pillows." The higher parts of each flow and the higher flows extend farther to the south and west. It is evident that the lava was extruded in an ancient valley and that each succeeding flow rose higher against the hill slope. At Twelfth Avenue and Thor Street, Spokane, the street cut exposes a similar contact. Here a single bed of fragmented lava and "pillows" rests with a very irregular contact on shale with fossil leaves of the Latah formation.

Russell,[13] in 1896, observed the contact in a cut made in grading for the street-car line where it turns east from Barnard Street on Eighth Avenue. This exposure is no longer visible, but as described by Russell and shown in his sketch the basalt rested on the shale with an uneven contact. Gravel and sand resting on micaceous clay, together with detached masses of the clay, extended upward into the inequalities of the under surface of the basalt. Russell believed that this basalt flow moved from west to east into a shallow lake, the bottom of which was disturbed and forced up into the ridges described above.

The lowest exposure of the "valley" flows is at the canyon of Deep Creek on Spokane River, at an altitude of about 1,650 feet. The higher flows reach an altitude of 2,100 feet in several localities in the eastern outskirts of Spokane and also near Mead and near Milan. These facts indicate a thickness for the flows of 450 feet. However, the well of the Davenport Hotel, after penetrating 60 feet of sand and gravel, passed through 370 feet of basalt, the base of the flows in this well being therefore at an altitude of about 1,520 feet. The difference between this altitude and 2,100 feet is 580 feet, which may be taken as the maximum known thickness.

These flows are generally massive and thick. Commonly they are separated into small irregular blocks by shrinkage cracks that cut them in different directions. They contrast with the older basalt in their general lack of vesicles and frothy lava. So far as observed they do not show a columnar jointing comparable to that of the flows composing the "rim rock." Small irregular columns occur, but large regular columnar jointing is rare. Locally the rock at Spokane Falls breaks into columns, but the columns are curved and comparatively small, and they stand at various angles. It is thought that the lack of regularity is due largely to the fact that the exposures most commonly observed in the vicinity of Spokane are near the margin of the flows, for in "The Cliff," a small remnant near Milan, columnar jointing is well developed (Pl. VI, *A*). A characteristic feature of the valley flows is a tendency to weather along widely spaced joints into columns, rounded pinnacles, and other forms, some of which assume an odd or fantastic appearance (Pls. VI, *B*, and VII, *A*). At the mouth of Deep Creek there is an unusually fine display of these huge masses loosened from their parent ledges and tumbled together in grand confusion (Pl. VII, *C*).

[13] Russell, I. C., U. S. Geol. Survey Water-Supply Paper 4, pp. 52–54, 1897.

Apparently they are the result of weathering along two or more sets of widely spaced joints.

The basalt is generally a fine-grained gray or black rock, but there is some variation between flows. Beds of a peculiar breccia occur along the margin of the basalt where it rests against the Latah formation. In this material, like plums in a pudding, are rounded masses of basalt from 1 to 6 feet in diameter (Pl. VII, *B*). They have a glassy outside coating from a quarter to half an inch thick and dense or vesicular interiors. These masses are of the type known as "pillows" and evidently broke free from the advancing flows as big drops of liquid lava. The exteriors cooled suddenly and therefore are glass, but the interiors cooled more slowly and are largely crystalline. In most of the masses the gases contained in the molten lava separated as bubbles, forming the vesicular and scoriaceous interior. "Pillow" structure in lava is usually attributed to extrusion of the lava into or under water.[14] The general presence of lava of this type near contacts and the change from solid sheets of basalt to "pillow" lava may be considered part of the evidence that the basalt of the younger series was extruded in valleys where the advancing flows moved into temporary water bodies near the sides of the valleys.

In the summer of 1924 Edward Sampson visited Deep Creek, and he has furnished the following account of the unique basalt breccia associated with the "pillow" lava.

> The pillow lava is displayed in great perfection on the east side of the Deep Creek canyon. In some places individual pillows, as is common in such lava, fit over the irregularities of those beneath, so that there is very little space between them. In other places the pillows are not closely packed but form only about half the total mass, and a few pillows are apparently wholly detached and surrounded by fragmental rock or breccia. This breccia is a loosely coherent mass of rough fragments averaging about a quarter of an inch across. The color is generally gray but in places is buff to yellow.
>
> Through the skill of C. S. Ross, both polished and thin sections were prepared by impregnation with a balsam-kololith mixture and with bakelite. Microscopic study of these sections shows that the fragments of the breccia are composed of basalt glass containing a few phenocrysts of plagioclase and a much less number of augite grains. Almost every fragment contains one or more vesicles through which the boundaries of the fragments pass at random. Obviously the fragments have been formed by the disruption of a glass that was already vesicular. Most of the fragments bear no oriented relation to adjacent fragments, but a few show only slight displacement from their neighbors.
>
> The fragments of the brown or buff rock are surrounded by a thin shell of material of unknown composition. In thin sections it is orange-colored and contrasts with the glass, which is dark brown. Part of the shell is moderately birefringent, and part appears isotropic, but the isotropism may be due to an extreme fineness of grain in an anisotropic substance. It seems unquestionable that the shell is formed by the alteration of the glass of the fragments, as feldspar laths project from unaltered glass into the yellow crust.

[14] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Suryve Bull. 199, pp. 113–117, 1902.

In the spaces between the fragments is a substance which from its optical properties is probably halloysite ($Al_2O_3.2SiO_2.nH_2O$) or allophane ($Al_2O_3.SiO_2.nH_2O$). It is gray to cream-colored, very soft and cheesy, with a hardness of about 3 in the Mohs scale. In thin section the mineral is opaque, but when crushed to a size passing a 200-mesh screen it is transparent. Such pieces are dark brown, perhaps owing to included air, but 24 hours' immersion in oil did not appreciably change the color. The mineral appears to be perfectly isotropic and has an index ranging from 1.46 to 1.47, owing to lack of uniformity. According to Larsen's tables, the properties recounted above are common to the minerals halloysite and allophane. The mineral does not completely fill the interstices, and it also has relatively wide cracks within its mass. Thus it appears to have shrunk in volume as if through the dehydration of a gel.

The present writer believes the view fairly well established that pillow lavas have formed by lava flowing into, over, or under water. It seems not improbable that the associated breccia has formed by the disruption of a basalt flow through the violent physical reaction of highly heated lava and water. Gas released from within the lava may have aided in this disruption, as indicated by the large number of vesicles.

From collections made by Mr. Henry Fair, Shannon [15] has identified a long list of minerals obtained from the vesicles in this basalt. The principal species are cristobalite, black opal, hyalite, and sphaerosiderite. The sphaerosiderite occurs as an incrustation similar to that found in the flows of the "rim rock," and also as hemispheres from a quarter to half an inch in diameter that are secondary and later in origin. Limonite and goethite replacing the sphaerosiderate are found.

At Deep Creek, 8 miles northwest of Spokane, black opal, opal and chalcedony replacing aragonite, and hyalite are present in cracks in "pillow" lava. Sphaerosiderite occurs alone in small gas holes of the basalt in a quarry near Milan. The minerals found in the younger flows all occur in artificial exposures except at the Deep Creek locality.

Specimens of the "valley" flows from the foot of Spokane Falls, the cut on Division Street, and the mouth of Deep Creek were examined by Mr. Calkins, who says:

They show to the unaided eye no consistent difference from the "rim rock" flows, though they are perhaps a little duller and more bluish. The blow holes in No. 15 (the specimen from Division Street) are almost wholly filled with hard iron oxide (goethite?). Their appearance under the microscope is highly characteristic. All are without olivine, which occurs in all the "rim rock" specimens; and the augite occurs in splintery or prismatic forms and seems to be nearly contemporaneous with the plagioclase, instead of distinctly later, as in the "rim rock" lava. These later flows are probably less magnesian than the older.

So far as positive evidence goes the flows in the valleys may be as young as early Pleistocene. Probably, however, they belong to the same period of volcanism that produced Columbia Plateau and other igneous features in the Northwest that are thought generally to belong within the Tertiary.

[15] Shannon, E. V., On siderite and associated minerals from the Columbia River basalt at Spokane, Wash.: U. S. Nat. Mus. Proc., vol. 62, pp. 1-19, 1923.

GRAVEL GROUP

Large deposits of unconsolidated or loosely coherent gravel occur in Spokane Valley and the valleys of Latah Creek and other streams. These deposits lie upon the eroded surface of the rocks previously described and are mostly of glacial origin. In the valley of Latah Creek and in that of Lake Creek near Marshall are large terraces at an altitude of about 2,300 feet built of gravel that contains much basalt and here and there a boulder of the fossiliferous shale. This gravel was deposited during a comparatively early Pleistocene stage of glaciation, described by Bretz [16] as the Spokane glaciation. The ice advanced from the north, crossing Fivemile Prairie, Pleasant Prairie, and other areas, from which it plucked masses of basalt and shale.

The floor of Spokane Valley and the extensive terraces along the river below Spokane up to an altitude of 2,000 feet are composed chiefly of gravel derived from granite and metamorphic rocks. This deposit is later than the other. Traced eastward it leads to a moraine at the south end of Pend Oreille Lake. Evidently it is outwash from a glacier that at a late stage, presumably Wisconsin, occupied the basin of that lake.

Both the older and younger members of the gravel group lie upon surfaces eroded across the valley flows. Evidently they were not deposited until after the greater part of these flows—all except the present remnants—had been cleared from the valleys.

SUMMARY OF THE GEOLOGIC HISTORY

The events of geologic time prior to the Tertiary period have left a record in the Spokane area only in the rocks of the granite-schist group. The story, doubtless much obscured, has not yet been deciphered, and so far as the events recorded in the rocks described in this paper are concerned the pre-Tertiary history is a closed chapter. The recital begins anew with the form of the pre-Latah surface, which indicates that by Miocene time the area was a mountainous land. Hills and mountains greater than those of to-day extended westward beyond Spokane, where now lie the relatively smooth plains of the Columbia Plateau. This mountainous region was doubtless wooded and well watered, for, wherever found, the ancient surface is composed of deeply weathered rock.

With the beginning of volcanism and the outpouring of basalt to the south and west, the drainage of the area became obstructed. In the ponded stream channels débris stripped from the mountains and dropped from the air as ash showers resulting from the explosions of distant volcanoes accumulated in the form of extensive sheets of gravel, sand, and clay. As basalt was built up sheet by sheet and as one lava

[16] Bretz, J. H., Glacial drainage on the Columbia Plateau: Geol. Soc. America Bull., vol. 34, pp. 573-608, 1923.

flow followed another, the Columbia Plateau was constructed. The flows, moving northeastward, extended farther with each successive outpouring and buried much of the old rugged highland, entering valleys, swinging around headlands, and completely surrounding isolated hills. Against this flood of lava the Silver Hill-Cheney Hills ridge and the doubtless more isolated hills to the west and north formed a barrier that almost wholly prevented the entrance of the molten lava into the Spokane area.

Behind this encircling ridge the streams poured sediment into quiet ponds, shallow swamps, and slowly-moving channels. Here the Latah formation was gradually built to a maximum thickness of 1,500 feet, and here were entombed in the clay the leaves, fruits, and twigs of the plants that grew in the area and also some remains of those that occupied higher ground.

Twice this area was partly invaded by lavas, as indicated by the record of the Hazelwood well, before it was finally overwhelmed by the flows of the "rim rock." When in this catastrophe the encircling ridge was overtopped the lavas not only covered the plain of alluviation but extended beyond it onto the lower slopes of the bordering mountains. These flows were fed from the west, but in addition there were local vents from which molten rock welled up from below through the Latah formation to augment the volume of the overlying lava.

After the invasion of the "rim rock" flows valleys deeper than those of to-day were cut in the basalt and the underlying shales of the Latah formation. Here new outpourings of basalt built up a plain nearly to the height of the "rim rock" flows.

Again the streams cut through these flows to a level below that of the present. Next they were obstructed by glacial deposits, first by débris deposited directly by a glacier from the north and next by gravel washed down from a glacier at Lake Pend Oreille. Immense floods carried the gravel from this source down Spokane Valley, filling it at Spokane to the 2,000-foot level. The Spokane Falls are an indirect result of this last filling. After clearing its valley up to the falls and incidentally producing extensive gravel terraces below Spokane, the river found itself placed at one side of its former channel and hung up, so to speak, on a ridge of basalt.

Thus it appears that since the old and rough surface of the granite-schist group of rocks became buried beneath the fossil-bearing shale and that formation was in turn covered by the flows of the "rim rock," the valleys of this area have been excavated, filled, and reexcavated, time after time. When Spokane River, therefore, has finally completed its task of reexcavating its valley, Spokane Falls, Coeur d'Alene Lake, and many other of the beautiful water bodies that form one of the chief attractions of this region will have disappeared. Save then for the "prairies" with remnants of leaf-bearing shale and their "rim rock" of basalt, the region will be largely restored to its condition before any of these events took place, and the cycle will be complete.

FLORA OF THE LATAH FORMATION OF SPOKANE, WASHINGTON, AND COEUR D'ALENE, IDAHO

By F. H. Knowlton

With a report on the diatom deposit by Albert Mann

INTRODUCTION

The geologic conditions under which the flora of the Latah formation occurs have been set forth at length in the preceding paper by J. T. Pardee and Kirk Bryan. Briefly summarized these conditions are as follows:

The area which has supplied the fossil flora herein described lies along the Columbia Plateau and the mountains of northern Idaho and northeastern Washington. It includes parts of the valleys of Spokane and Little Spokane rivers and adjoining parts of the mountains and the plateau.

The mountainous part of the area is composed principally of crystalline and metamorphic rocks, such as granite, gneiss, and schist, but includes small masses of quartzite. The topography is very rugged. The city of Spokane stands at the northeast corner of the Columbia Plateau, which stretches far away to the south and west and owes its general character to the fact that it is built up of vast lava flows that remain nearly as flat as they were when cooled.

The plant-bearing beds, to which the name Latah formation has been given by Messrs. Pardee and Bryan, consist mostly of shale or clay but include a few layers of sand and gravel. The colors of the beds range from pale yellowish gray to lead-gray or bluish gray, the prevailing shades being rather dull. These beds rest uncomformably on the granite-schist group and are overlain by the basalt flows. As they are very soft they are easily eroded and have been largely removed except where protected by the basalt, and consequently they are of rather small areal extent. The maximum thickness of the Latah formation is approximately 1,500 feet, though this thickness can not be noted at any one place.

Further details concerning the geologic and other relations will be found in the preceding paper.

SPECIES INCLUDED

As a preliminary to the consideration of the flora the following complete list of the forms thus far identified is given:

Archaeomnium patens E. G. Britton, n. gen. and sp.
Polytrichites washingtonensis E. G. Britton, n. gen. and sp.
Moss, genus and species?
Fern, fragment.
Ginkgo adiantoides (Unger) Heer.
Equisetum, underground stem.
Lycopodium hesperium Knowlton, n. sp.
Tumion bonseri Knowlton, n. sp.
Pinus sp.
Sequoia langsdorfii (Brongniart) Heer.
Sequoia? sp.
Taxodium dubium (Sternberg) Heer.
Taxodium, male aments.
Libocedrus praedecurrens Knowlton, n. sp.
Typha? sp.
Potamogeton sp.
Grass, leaf.
Grass?, genus?
Arisaema hesperia Knowlton, n. sp.
Populus heteromorpha Knowlton, n. sp.
Populus fairii Knowlton, n. sp.
Populus lindgreni Knowlton.
Populus washingtonensis Knowlton, n. sp.
Salix remotidens Knowlton, n. sp.
Salix elongata O. Weber.
Salix perplexa Knowlton.
Salix inquirenda Knowlton, n. sp.
Salix bryani Knowlton, n. sp.
Salix dayana Knowlton.
Salix sp.
Alnus, cones.
Betula fairii Knowlton, n. sp.
Betula nanoides Knowlton, n. sp.
Betula heteromorpha Knowlton.
Betula thor Knowlton, n. sp.
Betula? largei Knowlton, n. sp.
Betula bryani Knowlton, n. sp.
Carpinus sp.
Castanea castaneaefolia (Unger) Knowlton.
Quercus merriami Knowlton.
Quercus bonseri Knowlton, n. sp.
Quercus cf. Q. pseudo-lyrata Lesquereux.
Quercus rustii Knowlton, n. sp.
Quercus spokanensis Knowlton, n. sp.
Quercus payettensis Knowlton.
Quercus praenigra Knowlton, n. sp.
Quercus simulata Knowlton.
Quercus chaneyi Knowlton, n. sp.
Quercus obtusa Knowlton, n. sp.
Quercus, cup.
Quercus, acorn.
Ulmus speciosa Newberry.
Ulmus fernquisti Knowlton, n. sp.
Ficus? washingtonensis Knowlton, n. sp.
Laurus similis Knowlton.
Laurus princeps Heer.
Laurus californica Lesquereux.
Laurus grandis Lesquereux.
Magnolia dayana Cockerell.
Magnolia sp.
Liquidambar pachyphyllum Knowlton.
Liquidambar, fruit.

Hydrangea bendirei (Ward) Knowlton.
Prunus rustii Knowlton, n. sp.
Cercis? spokanensis Knowlton, n. sp.
Sophora alexanderi Knowlton, n. sp.
Sophora spokanensis Knowlton, n. sp.
Robinia? sp.
Meibomites lucens Knowlton, n. gen. and sp.
Celastrus fernquisti Knowlton, n. sp.
Rhus typhinoides Lesquereux.
Acer bendirei Lesquereux.
Acer merriami Knowlton.
Acer minor Knowlton.
Acer chaneyi Knowlton, n. sp.
Vaccinium salicoides Knowlton, n. sp.
Diospyros andersonae Knowlton n. sp.
Diospyros? microcalyx Knowlton, n. sp.
Malva? hesperia Knowlton, n. sp.
Phyllites amplexicaulis Knowlton, n. sp.
Phyllites crustacea Knowlton, n. sp.
Phyllites pardeei Knowlton, n. sp.
Phyllites sophoroides, n. sp.
Phyllites peculiaris Knowlton, n. sp.
Phyllites relatus Knowlton, n. sp.
Phyllites sp.
Carpites menthoides Knowlton, n. sp.
Carpites boraginoides Knowlton, n. sp.
Carpites polygonoides Knowlton, n. sp.
Carpites spokanensis Knowlton, n. sp.
Carpites ginkgoides Knowlton, n. sp.
Carpites magnifica Knowlton, n. sp.
Carpites paulownia Knowlton, n. sp.
Branchlet and bud?

RELATIONS OF THE FLORA

As already set forth in detail in the geologic account by Messrs. Pardee and Bryan, the plants of the Spokane area occur in layers of clay associated with basalt flows. The stratigraphic relations of the plants from the Coeur d'Alene area are not so definitely known, but as a number of the species are identical with those of the Spokane area the age and structural relations are also presumably nearly identical.

The primary object of the study of this flora was to ascertain its bearing on the age of the basalt flows with which the plant-bearing beds are so intimately associated. Spokane is at practically the northeastern limit of the great basalt flow, the so-called Columbia River basalt, one of the greatest bodies of lava in the world, which has an area of approximately 250,000 square miles, including the greater part of Washington, eastern Oregon, much of northern California, and the great Snake River Plain in Idaho. As the fossil plants obtained from the sediments associated with these flows afford the most extensive paleontologic data for the determination of their age, the study of the present collection is of great stratigraphic value.

Before discussing the floras from Spokane and Coeur d'Alene it is necessary briefly to review certain floras and formations with which these may be compared.

COMPARABLE FLORAS IN OTHER FORMATIONS

PAYETTE FORMATION

The Payette formation, named by Lindgren,[1] is a series of lake-bed deposits having a maximum thickness of 1,000 feet in the lower part of the Snake River valley, Idaho. Fossil plants were found in these beds at four localities. The total flora then recognized numbered 32 species, of which 17 were regarded as new to science and 5 were not named specifically, leaving, as then known, only 10 species having an outside distribution. As 6 of these 10 forms were regarded as identical with described species from Bridge Creek, Oreg., and several others as closely related to Bridge Creek species, it was concluded that the Payette formation was of the same age as the beds at Bridge Creek, which were then regarded as upper Miocene.

The age determination of the plant-bearing beds in the John Day Basin, Oreg., that was then current was based largely on the earlier work of Lesquereux, but the localities were not differentiated, all being grouped under the designation "John Day Basin." Although it was of course noted that there were marked differences in the matrix bearing the plants, the specimens were all supposed to be of approximately the same age—that is, upper Miocene.

Subsequently (1900) John C. Merriam visited the John Day Basin and worked out in detail the stratigraphic relations of the Tertiary deposits. To the oldest of these deposits, a series of beds some 400 feet in thickness, composed of rhyolite and andesite flows and ash and tuff beds resting on Cretaceous rocks, Merriam gave the name Clarno formation. The Bridge Creek locality is in the extreme upper part of the Clarno formation and the age was considered to be upper Eocene.

The next higher plant-bearing beds above the Clarno were named by Merriam the Mascall formation. This formation is a series of sediments from 800 to 1,000 feet in thickness, composed largely of ash and tuff, generally light in color. Near the base of this formation is the well-known Van Horn or Belshaw ranch locality. The Mascall was considered to be of middle Miocene age.

With this digression we may now return to the Payette formation. In my "Fossil flora of the John Day Basin"[2] I discussed certain floras that are more or less closely related to those of the John Day region, among them that of the Payette formation. As this flora is clearly related to that of the Bridge

[1] Lindgren, Waldemar, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 632, 1898.
[2] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 110, 1902.

Creek locality, which had in the meantime been relegated to the upper Eocene instead of the upper Miocene, I felt justified in regarding the age of the Payette as the same, namely, upper Eocene. This reassignment was met with protest by the geologists, but on the basis of the material then available this was the logical conclusion to be drawn.

The matter has been held in abeyance pending the discovery of additional data, and these have now in a measure been supplied by the investigations of Dr. R. W. Chaney, of the Carnegie Institution of Washington. In 1921 Chaney visited the Snake River valley and procured collections from one or two of the original localities as well as from some four or five other points, with the result that the original flora of 32 species is increased by 17 species, bringing the total flora now recognized up to 49 species. The preliminary results of Chaney's studies are set forth in a short paper[3] published in 1922. First it may be pointed out that he is now of the opinion that a further change in the age assignment of the flora from Bridge Creek is probable. He says:

> The writer has not yet brought together all the necessary evidence, but recent field studies in the John Day Basin and at other points in eastern and central Oregon point to the placing of the Upper Clarno formation in the Oligocene rather than in the Eocene. If this is correct, and the supporting evidence will be brought forth in a subsequent paper, there are no atypical Eocene plants in the Payette flora.

At the time of the original discussion of the Payette flora only 10 of the 32 species had a known distribution beyond this formation, but by the work of Chaney the number has been increased to 21. His analysis discloses that 12 of the 21 species occur in the Mascall formation (middle Miocene) and only 5 species in the flora from Bridge Creek (upper part of the Clarno formation). Although mere numerical superiority may not be the safest criterion for correlation, it has distinct value.

There are, however, other criteria that point to the Miocene age of the Payette formation. Thus the position of the formation, above basalt lavas, is in accord with the relations of the Mascall formation to the Columbia River lavas in the John Day Basin. Further, vertebrate remains from the Payette found by J. P. Buwalda are pronounced by him to be of middle or upper Miocene age. It seems, therefore, that the conclusion reached by Chaney must be accepted, namely, that the Payette formation is probably of Miocene age. He says:

> So far as the plants are concerned, the age would not be younger than middle Miocene, and in view of the inclusion of Oligocene and possibly Eocene forms, it might better be considered as lower Miocene. The present knowledge of the western floras does not justify an attempt to draw the line of age too sharply, and at the present time the writer is satisfied to make the reference to the Miocene without further specification.

[3] Chaney, R. W., Notes on the flora of the Payette formation: Am. Jour. Sci., 5th ser., vol. 4, pp. 214-222, 1922.

EAGLE CREEK FORMATION

The Eagle Creek formation is a very thick series of beds of volcanic conglomerate, ash, and tuff, with some intrusions of basalt, exposed in the Columbia River gorge, mainly in Multnomah County, Oreg., and across the river in Skamania County, Wash. The flora, described by Chaney,[4] is a comparatively rich one, comprising 72 species, of which 38 are described as new and 14 are not named specifically, leaving 20 species with an outside distribution. An analysis of the range of these species shows that the greater number are found in the flora from Bridge Creek, in the John Day Basin, and that a considerable number are common also to the Mascall flora. At the time Chaney's paper was written the flora from Bridge Creek was considered to be upper Eocene.

From a comparison of the species having an outside distribution, as well as the distribution of species obviously closely related to certain of the new forms, Chaney concluded that the Eagle Creek flora seemed to show a transition between Eocene and Miocene. He says:

> While most closely related to floras of upper Eocene age, the Eagle Creek flora is also definitely related to those of Miocene age, if these formations have been correlated correctly. On the basis of these relations it has seemed proper to consider the Eagle Creek flora as transitional between the upper Eocene and Miocene, or, in other words, of Oligocene age.

In view of what was brought out above regarding the flora from Bridge Creek, to which that of the Eagle Creek is obviously related, it is probable that the Eagle Creek would now be regarded by Chaney as of Miocene age.

AURIFEROUS GRAVELS IN CALIFORNIA

In 1878 Lesquereux[5] published a paper on the fossil plants of the auriferous gravel deposits of the Sierra Nevada, in which he describes over 50 species. From their apparent close affinity with living species, their more or less close agreement with certain European floras, and their association with vertebrate remains, they were considered to be of Pliocene age. In later years, as additional stratigraphic data and collections of plants became available, it came to be accepted that the plant-bearing beds, or at least those which supplied most of Lesquereux's material, were upper Miocene. As more and more intensive stratigraphic work was done in the Sierra Nevada it became evident that the so-called auriferous gravels represent a phase of sedimentation that was comparatively long, extending from upper Eocene time well into and possibly through the Miocene. The localities most frequently mentioned (such as Table Mountain, Tuolumne County, and Chalk Bluffs, Nevada County) fall within the Miocene.

[4] Chaney, R. W., Flora of the Eagle Creek formation: Chicago Univ. Walker Mus. Contr., vol 2, No. 5, pp. 1 5-181, pls. 5-22, 1920.

[5] Lesquereux, Leo, Harvard Univ. Mus. Comp Zoology Mem , vol. 6, No. 2, pp. i-vi, 1-62, pls. 1-10, 1878.

MASCALL FORMATION

The position of the Mascall formation is briefly referred to above in the section on the Payette formation. The flora of the Mascall formation was described in 1902 in my "Fossil flora of the John Bay Basin, Oregon," [6] and embraces about 80 species. As already pointed out, the affinity of this flora is with the Miocene, and from its stratigraphic position, as well as from the vertebrate remains, the position is fixed with much certainty as middle Miocene.

ELLENSBURG FORMATION

The Ellensburg formation, which was named by Geo. Otis Smith,[7] comprises certain fluviatile deposits of stratified silt, sand, and gravel of volcanic materials near Ellensburg, Wash., about 150 miles west of the Spokane area. The older of these beds are overlain by or interbedded with the Wenas basalt. Fossil plants have been found in the formation at two localities, one about 6 miles southeast of Ellensburg and the other in Kelly Hollow, Wenas Valley, some 15 miles south of Ellensburg. The matrix is a white, generally fine-grained volcanic ash, identical in appearance with that from the Van Horn ranch (Mascall formation), in the John Day Basin, Oreg.

[6] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 106, 1902.
[7] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), p. 2, 1903.

The Ellensburg flora numbers 15 species, 13 of which are found in greater or less abundance in the Mascall formation of the John Day Basin, and on this basis the Ellensburg formation is considered to be of the same age, namely, middle Miocene. Four or five of the species from the Spokane area are identical with or closely allied to species identified in the Ellensburg formation.

FLORAS OF THE SPOKANE AND COEUR D'ALENE AREAS

With the above background we may now consider the floras of the Spokane and Coeur d'Alene areas. The most striking feature of these floras at first glance is their very modern appearance, and the apparent living analogues are at once suggested for many of the forms, especially in *Ginkgo, Sequoia, Taxodium, Populus, Castanea, Quercus, Ulmus,* and *Acer*. It was the very modern aspect of the flora of the auriferous gravels of California, as well as its resemblance to certain European floras, that led Lesquereux originally to refer it to the Pliocene.

An analysis of the 95 forms that make up the Spokane and Coeur d'Alene floras shows that 25 species have a distribution outside these areas. The following table shows the vertical distribution of these 25 species:

Vertical distribution of the extralimital species of the Spokane and Coeur d'Alene floras

	Lance formation	Fort Union formation	Kenai formation	Clarno formation	Eocene	Payette formation	Oligocene	Eagle Creek formation	Mascall formation	Auriferous gravels	Miocene	Pliocene
Ginkgo adiantoides	×	×	×		×		×	×				
Sequoia langsdorfii	×	×	×	×					×		×	
Taxodium dubium	×	×	×	×					×		×	×
Populus lindgreni						×			×			
Salix elongata											×	
Salix perplexa							×?		×			
Salix dayana									×			
Betula heteromorpha				×				×	×			
Castanea castaneaefolia									×	×		
Quercus merriami								×	×			
Quercus cf. Q. pseudo-lyrata								×	×			
Quercus payettensis						×						
Quercus simulata						×		×				
Ulmus speciosa				×			×?	×				
Laurus similis					×?			×				
Laurus princeps		×?				×				×		
Laurus californica										×	×	
Laurus grandis										×	×	
Rhus typhinoides								×?		×		
Magnolia dayana				×						×	×	
Acer minor									×			
Acer bendirei									×		×	
Acer merriami									×			
Liquidambar pachyphyllum								×	×			
Hydrangea bendirei									×			
	3	4	3	5	2	3	3	9	13	6	7	1

The first three species in the above list have so wide a vertical range that they are of comparatively little value in fixing the age. Another possible element of uncertainty may hinge upon the correctness of all the identifications. Conifers are not always easy to identify with certainty unless they are exceptionally well preserved. As the three species now stand they range from Lance to Miocene—indeed, one (*Taxodium dubium*) persists into the Pliocene, and this one connects with the living species (*Taxodium distichum*) with very little if any change. As a matter of fact it is difficult to draw a satisfactory line between what is now called *Taxodium dubium*—which was long known as *Taxodium distichum miocenum*—and the living species.

A glance at the above table discloses the fact that the flora of the Spokane and Coeur d'Alene areas finds its closest agreement with the floras of the Mascall formation, the auriferous gravels, and the Miocene in general, 13 of the 25 species being common to the Mascall, 6 to the auriferous gravels, and 7 to the undifferentiated Miocene, or altogether no less than 19 species. The Latah formation has 5 species found in the upper part of the Clarno formation (Bridge Creek locality) 3 in the Payette formation, and 2 in the Eagle Creek formation, or 9 species in these three formations.

As already pointed out, the Mascall formation of the John Day Basin, Oregon, is now very definitely fixed as middle Miocene in age, and as the latest determination seems to place the upper part of the Clarno, the Payette, and the Eagle Creek floras also in the Miocene the conclusion seems justified that the Spokane and Coeur d'Alene floras (Latah formation) are of Miocene age. This flora is therefore regarded as not younger than middle Miocene and not older than lower Miocene.

This assignment of position is still further emphasized by the distribution of the species to which certain of the new species are obviously related. This is shown in the following table:

Horizons of species related to the Spokane and Coeur d'Alene plants

	Most closely related fossil species	Horizon
Pinus sp	Pinus knowltoni	Eagle Creek.
Taxodium, male aments	Taxodium, male aments	Mascall.
Carpinus sp	Carpinus grandis	Mascall and Eocene.
Quercus bonseri	{Quercus pseudo-lyrata Quercus merriami}	Mascall.
Quercus cf. Q. pseudo-lyrata	Quercus pseudo-lyrata	Do.
Quercus rustii	{Quercus payettensis Quercus merriami	Payette. Mascall.
Quercus spokanensis	Quercus cowlesi	Eagle Creek.
Quercus chaneyi	Quercus simplex	Upper part of Clarno.
Ulmus fernquisti	Ulmus californica	Auriferous gravels.
Ficus? washingtonensis	Ficus sordida	Do.
Prunus sp	Prunus? tuffacea	Mascall.
Celastrus fernquisti	Celastrus taurinensis	Fort Union.
Acer chaneyi	Acer angustilobatum	Swiss Miocene.

Of the 13 species in this list 6 are more or less closely related to forms in the Mascall formation, 2 each to species in the Eagle Creek and auriferous gravels floras, and 1 each in the Payette, upper part of Clarno, Fort Union, and Swiss Miocene.

Many of the forms found in the floras from Spokane and Coeur d'Alene are so modern in appearance that it may be of interest to note the obvious living affinities of the new species. This is brought out in the following table:

Relation of new species of Spokane and Coeur d'Alene plants to species now living

New fossil species	Related living species
Archaeomnium patens	Aulacomnium palustre.
Polytrichites washingtonensis.	Polytrichum sp.
Lycopodium hesperium	Lycopodium carolinianum.
Tumion bonseri	Tumion californicum.
Libocedrus praedecurrens	Libocedrus decurrens.
Typha sp	Typha latifolia.
Potamogeton sp	Potamogeton heterophylla.
Arisaema hesperia	Arisaema triphyllum.

Relation of new species of Spokane and Coeur d'Alene plants to species now living—Continued

New fossil species	Related living species
Populus heteromorpha	{Populus alba. Populus canescens.
Salix bryani	Salix discolor.
Alnus, cones	Alnus incana.
Betula nanoides	Betula humilis.
Betula? largei	Betula papyrifera.
Betula bryani	Betula papyrifera.
Betula thor	Betula papyrifera.
Quercus spokanensis	{Quercus michauxii. Quercus prinos.
Quercus praenigra	Quercus nigra.
Quercus chaneyi	Quercus virginiana.
Quercus obtusa	Quercus virginiana.
Quercus, cup	Quercus lyrata.
Ulmus fernquisti	Ulmus fulva.
Magnolia sp	Magnolia foetida.
Prunus sp	Prunus americana.
Cercis? spokanensis	Cercis canadensis.
Robinia	Robinia pseudoacacia.
Meibomites lucens	Meibomia arenicola.
Diospyros andersonae	Diospyros virginiana.
Diospyros? microcalyx	Diospyros texana.
Malva? hesperia	Malva spp.
Vaccinium salicoides	Vaccinium pennsylvanicum.
Carpites paulownia	Paulownia tomentosa.

COMPARISON OF THE FLORAS FROM THE SPOKANE AND COEUR D'ALENE AREAS

Most of the plants described in this report came from the Spokane area, but a single large and interesting collection, submitted by Mr. H. J. Rust, was obtained near the bottom of a well 43 feet deep on the south slope of Stanley Hill, about 2 miles northeast of Coeur d'Alene, Idaho. No detailed stratigraphic study has been made of the Coeur d'Alene area, but at my suggestion Mr. Pardee made a hasty examination in July, 1923. He states that no exposures of the fossiliferous beds were seen, but "remnants of basalt flows that appear to overlie the fossil-bearing shale crop out near by, and a little farther away granite and schist that form the bedrock are exposed." Mr. Pardee is therefore of the opinion that the relations at Coeur d'Alene are in general similar to those at Spokane.

The Coeur d'Alene flora comprises 25 forms, of which 13 are regarded as new, 3 are not named specifically, and 9 are previously known species. It is especially rich in oaks, as regards both species and individuals, probably more than half of the individuals belonging to the oaks. Only the following 6 species are common to the Spokane area:

Taxodium dubium.
Sequoia langsdorfii.
Betula heteromorpha.
Quercus merriami.
Ficus? washingtonensis.
Prunus rustii.

In one way it seems rather strange that there is not more in common between the two areas, which are separated by only 25 miles, but comparison of the lists of plants from the several Spokane collections shows that there are few species common to two localities that are separated even by only a few feet vertically or a few miles areally. This localization is doubtless to be ascribed to two sources—the accident of fossilization and the extent of exploitation. In one locality a shower of oak leaves may fall or be blown into the water and if not transported to any great distance may dominate the deposits. In another locality scattered leaves of many kinds may find a resting place in proximity.

ECOLOGIC CONDITIONS

The accompanying illustrations show that many of the species, such as the poplars, oaks, elms, and alders, have a very modern appearance. By using their obvious affinities with living species it is possible to deduce certain conclusions regarding the probable ecologic conditions and climate under which these plants lived.

The physical setting that preceded and accompanied the entombment of these plant remains has been fully discussed by Messrs. Pardee and Bryan in the preceding paper and will be only briefly recapitulated here. The basement or floor on which the lavas and associated sediments rest is composed mainly of crystalline and metamorphic rocks, such as granite, gneiss, and schist, and had developed a topography which "was apparently even more rough than the mountainous lands north and east of the plateau are at present." When the lava was extruded it spread in a broad sheet, filling the depressions, and as it advanced upon the mountainous region it projected into the mountain valleys and retired around the intervening spurs "like the coast line of a sea." As it pressed up the valleys it obstructed the streams, producing ponds and possibly small lakes. The appearance and composition of the fossil-bearing shale are described by Messrs. Pardee and Bryan (pp. 4–10).

In this flora three fairly well differentiated ecologic types can be distinguished—hydrophytes, mesophytes, and xerophytes. The hydrophytes include what appears to be a leaf of *Potamogeton,* of a type growing in shallow water with leaves both submerged and floating. There are also leaves of *Typha,* which presumably lived in very shallow water or in flats continually or periodically inundated. At one of the localities, the well at Mica, there are numerous fresh-water diatoms. A report on these diatoms, with an interpretation of the probable conditions under which they lived, is given by Dr. Albert Mann on pages 51–55.

The mesophytes are apparently the most abundant element in the flora. The species represented by the greatest number of individuals are *Populus heteromorpha* and *Taxodium dubium,* of which there are literally hundreds of specimens. Their abundance and their perfect preservation shows that they must have grown very near where they were entombed. The *Taxodium,* if it has been correctly interpreted, probably grew in swamps either along streams or on the borders of the ponds. The poplars probably grew along the streams, together with the several species of willows and the alders, and their leaves fell directly into the ponds or lakes, as they show little effect of transportation. On slightly higher ground back from the streams were the magnolias, maples, and chestnuts and possibly some of the oaks, together with the huckleberries, laurels, and elms.

The xerophytes or semi-xerophytes probably clothed the ridges. These are the several species of oaks that have more or less coriaceous leaves. The oak leaves are perhaps third in abundance of individuals, and the fact that only a few acorns are preserved would seem to indicate that the trees were some distance from the streams or ponds, into which the leaves could be easily transported by winds.

It is not always easy to differentiate between mesophytic and xerophytic assemblages, for in the living floras it usually happens that there is more or less of a commingling of the two elements. As Chaney [8] has said:

[8] Chaney, R. W., Chicago Univ. Walker Museum Contr., vol. 2, No. 5, p. 246, 1920.

In modern forests there is a degree of mixture of ecological types, due to the lagging behind of certain relict xerophytes after the plant association has become mesophytic, or to the advance into a xerophytic association of certain pioneer mesophytes. In the first case mentioned the plants would be dominantly mesophytic with scattered xerophytes; in the second case the plants would be dominantly xerophytic with scattered mesophytes.

We may now draw a picture of the probable physical setting in the Spokane area when these plants were entombed. The area was a broad valley flanked by rolling hills and ridges, some of which rose 1,500 feet or more above the general level, with considerable streams coming down from the north or northeast. Then came the lava flow, which completely dammed the streams, throwing the water back into shallow lakes or ponds. As the lava was eroded slowly the ponding continued for a sufficient length of time for a considerable growth of trees, shrubs, and smaller herbaceous plants. The open bodies of water were teeming with microscopic diatomaceous life. Here and there pondweeds floated on the surface, and about the borders were patches of cattails, grasses, and sedges. In the swamps adjacent to the open water were the forests of bald cypress and an occasional soft maple. Overhanging the streams and in places along the borders of the ponds were the alders and willows and also the poplars, of which there were several kinds, some of them doubtless forming groves back from the water. On the slopes and foothills there were forests of deciduous trees, including elms, maples, magnolias, laurels, and some oaks. In the moist, rich, shaded parts were Indian turnips and doubtless other more or less herbaceous growth. Still higher were the groves of oaks of several kinds, with a few chestnuts and scattered clumps of pine. It is hard to place the position of the sequoia and ginkgo, but probably they were on the middle slopes.

CLIMATE

The composition of the flora of the Spokane and Coeur d'Alene areas indicates that it was distinctly a temperate assemblage, if the plants had approximately the same climatic requirements as their living allies, as there is every reason to suppose they had. It was a flora very similar to that now living in the northeastern part of the United States.

INSECT REMAINS IN THE LATAH FORMATION

Although the clay shale in which the plants are preserved with such remarkable fidelity is very fine grained and in every way fitted for the preservation of insect remains, such remains are exceedingly rare—in fact, so far as has come to my knowledge, only three specimens have been found. These are the elytra of a large carabid beetle, apparently of a single species. The first one found was submitted to Prof. T. D. A. Cockerell, of the University of Colorado, who named and described it as *Calosoma fernquisti*.[9] It was named in honor of the collector.

SUMMARY

The flora herein described comes from the vicinity of Spokane, Wash., and Coeur d'Alene, Idaho. It occurs mainly in clay shale associated with the lava flows of the Columbia Plateau. These plant-bearing beds, to which the name Latah formation has been given, have a minimum thickness in the Spokane area of approximately 1,500 feet.

This flora comprises 95 forms, of which 51 are regarded as new to science, 18 are not named specifically, and 25 are found in other areas.

As a whole this flora is very modern in appearance, the ginkgo, cypress, sequoias, oaks, elms, maples, poplars, and others being especially similar to certain living analogues.

This flora has been compared with floras from the auriferous gravels of California, the Eagle Creek formation of Oregon and Washington, the upper part of the Clarno formation (Bridge Creek locality) and the Mascall formation of the John Day Basin, Oregon, the Payette formation of Idaho, and the floras at Elko, Nev., and Ellensburg, Wash., as well as with more distant Eocene and Miocene floras.

Of the 25 species having an outside distribution, 3 occur in the Lance formation, 4 (1 doubtful) in the Fort Union, 3 in the Kenai, 5 in the Clarno, 2 (1 doubtful) in the Eocene, 3 in the Payette, 3 in the Oligocene, 9 in the Eagle Creek, 5 in the Ellensburg, 13 in the Mascall, 6 in the auriferous gravels, 7 in other Miocene beds, and 1 in the Pliocene. Six (1 doubtful) of the 25 species occur in beds of established Eocene age, but only one is confined to these beds. On the other hand, 19 of the 25 species occur in accepted Miocene or higher beds. This leaves the upper part of the Clarno, the Payette, and the Eagle Creek formation, with 9 species in common, which have usually been considered as of upper Eocene age but which are now regarded as probably lower Miocene.

The affinity of the floras from the Spokane and Coeur d'Alene areas is undoubtedly with the higher beds, and the conclusion is reached that they are of Miocene age. They are not younger than middle Miocene nor older than early Miocene.

THE FLORA

Phylum BRYOPHYTA

Class MUSCI

In the collections made by various people in the Spokane region there are a number of fairly well preserved mosses. These were all submitted to Mrs. E. G. Britton and Dr. Arthur Hollick, of the New

[9] Cockerell, T. D. A., U. S. Nat. Mus. Proc., vol. 64, p. 14, pl. 2, fig. 8, 1924.

York Botanical Garden, and Mrs. Britton has been kind enough to prepare the following identifications and diagnoses.

Family MNIACEAE

Genus ARCHAEOMNIUM E. G. Britton, n. gen.

With the characters of the species.

Archaeomnium patens E. G. Britton, n. sp.

Plate VIII, Figures 1, 2

Plants up to 2 centimeters high by 3 millimeters broad; stems simple or branched, erect, apparently tomentose, with one branch bearing a curved, leafless apical prolongation about 1 centimeter in length; leaves crowded and spreading, larger and more numerous at the apex of the stems, lanceolate-acuminate, about 1.5 millimeters long by 0.5 millimeter broad, seemingly entire and costate to apex, with revolute margin.

Resembles the living species *Aulacomnium palustre* (Linné) Schwaeger in the leafless prolongation of the stem with a slight induration of a capitate tip, the presence of tomentum, and the larger crowded apical leaves.

Occurrence: Latah formation, cut No. 1 on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, June, 1922.

Family POLYTRICHACEAE

Genus POLYTRICHITES E. G. Britton, n. gen.

With the characters of the species.

Polytrichites spokanensis E. G. Britton, n. sp.

Plate VIII, Figures 3, 4

Plant erect or slightly decumbent at base; stems up to 2 centimeters high, branching; leaves not crowded except at the summit of the stems, composed of two distinct portions—a paler basal part, which is erect, appressed, and clasping the stem, and an apical part, which is bent outward and spreading, which measures 3 to 4 millimeters in length, is evidently strongly veined and keeled, apparently entire and sharply subulate.

Although much resembling, when magnified, certain living species of *Polytrichum*, the actual size of the plant precludes any definite reference to this genus.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, June, 1922.

Moss, genus and species?

Plate VIII, Figures 5, 6

Notwithstanding the extensive collecting that has been done in the Spokane area mosses appear to be but poorly represented though evidently diversified, for of the three specimens thus far found two are described above as new genera; the third specimen is here figured. It consists of several densely leafy stems that it seems to me might without violence be referred to *Polytrichites*, described above, but it has passed under the critical eye of Mrs. Britton, and she considers it too obscurely preserved to permit adequate diagnosis, and it must therefore remain without a name. It is presented simply to show that this type of vegetation is present.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, April, 1922.

Phylum PTERIDOPHYTA

Fern, fragment

Plate IX, Figure 10

Among several hundreds of specimens that have been studied from the Spokane area this is the only fern observed, and it, of course, has no value beyond indicating the presence of this plant type. It is the basal portion of a pinna or pinnule that was evidently coriaceous and has a very strong midvein and numerous strong veins that arise at an angle of about 45°. The veins fork just as they emerge from the midvein and twice or three times before reaching the margin. None of the margin is retained except the base, and this is entire.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, May, 1923.

Class EQUISETALES

Family EQUISETACEAE

Equisetum, underground stem

Plate IX, Figure 1; Plate XXVI, Figure 5; Plate XXIX, Figure 8

Equisetum was apparently a rare element in this flora, as only three specimens have been found thus far. The best preserved is a segment of an underground stem with three groups of opposite, sessile, large tubercles. The stem has four or five strong, somewhat irregular longitudinal ridges. The tubercles are unusually large, spherical or nearly so, marked with strong ridges.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway in Spokane, Wash., collected by Henry Fair and C. E. Fernquist, June, 1922.

Order LYCOPODIALES

Family LYCOPODIACEAE

Lycopodium hesperium Knowlton, n. sp.

Plate VIII, Figure 7

Sterile stems unknown; fertile spike erect, very slender, over 3.5 centimeters long, about 3 millimeters in diameter; bracts apparently cordate, short acuminate at apex, the margins entire, with the oval sporangia in their axils.

The fragmentary specimen, the only one found in the collections, lacks both base and apex and was probably at least 4 centimeters long. It is unfortunate that a leaf-bearing portion of the stem is not preserved. Among living species it appears to approach most closely *Lycopodium carolinianum* Linné, of the moist pine barrens from New Jersey to Florida and Louisiana, especially near the coast. This species has the bracts cordate, short acuminate, and mostly entire, thus agreeing with the fossil so far as the latter can be made out.

Only five species of *Lycopodium* have been reported in a fossil state in this country.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Phylum SPERMATOPHYTA

Class GYMNOSPERMAE

Order GINKGOALES

Family GINKGOACEAE

Ginkgo adiantoides (Unger) Heer

Plate VIII, Figures 10, 11

Ginkgo adiantoides (Unger) Heer, Flora fossilis arctica, vol. 5, Abt. 3, p. 21, pl. 2, figs. 7–10, 1870.
Ward, U. S. Geol. Survey Sixth Ann. Rept., p. 549, pl. 31, figs. 5, 6, 1886; idem, Bull. 37, p. 15, pl. 1, figs. 5, 6, 1887.
Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 159, pl. 5, fig. 1, 1920.

Thus far only three leaves of *Ginkgo* have been found in the Spokane area. One was collected in 1910 and the others in April and June, 1923, and as collecting in the area has been intensive between these dates it is safe to assume that *Ginkgo* was not a very conspicuous element of this flora.

In all the specimens the leaf substance is so well preserved that the leaf can be removed from the matrix intact and mounted between small plates of glass. This condition is unusual—in fact, these are the only leaves of *Ginkgo* that I have seen that could be completely removed from the matrix. There are, however, a few coniferous leaves in the Spokane material that are equally well preserved. (See *Tumion*, pp. 25–26.) Their thick, leathery texture and resinous nature are doubtless the reason for their excellent preservation.

Ginkgo is a very ancient type that has come down to the present with very little change, at least in the leaves. There is a considerable range in the degree of lobation in the leaves of *Ginkgo biloba*, the only living species, some being practically entire and others so deeply lobed as to be almost bisected. *Ginkgo* was a very abundant element in the Jurassic flora, and a good many nominal "species" have been differentiated, yet it is seemingly possible to duplicate many of these forms among the various forms of the living species, and differentiation is increasingly difficult as we ascend in the geologic time scale. Although the leaves from Spokane appear to be identical with what has been called *Ginkgo adiantoides* (Unger) Heer, they are practically identical with certain forms of the living species. The margin is undulate with but slight indentation of the central sinus, and in this particular the form agrees with specimens so identified by Chaney [10] from the Eagle Creek formation, where it is abundant.

Occurrence: Latah formation, in S., P. & S. cut No. 1, Spokane, Wash., collected by T. A. Bonser, specimen now in the U. S. Nat. Mus., No. 37192; in S., P. & S. cut No. 3, Spokane, collected by Leland Hirst, April, 1923 (Pl. VIII, fig. 10); in the gully at Fivemile Prairie, east of Spokane, collected by Miss Arleen Schmidt, June, 1923 (Pl. VIII, fig. 11). The last two specimens preserved in the Spokane Public Museum.

Order CONIFERALES

Family TAXACEAE

Subfamily TAXEAE

Tumion bonseri Knowlton, n. sp.

Plate X, Figure 3

This species is based on the fragment of branchlet figured. It is a segment about 5 centimeters long, broken from what was evidently a long, stout branchlet which is nearly 3 millimeters in diameter. The leaves are scattered at remote and somewhat unequal distances and are inserted spirally but become two-ranked by a twist of the petiole. They are 2.5 to 3 centimeters long and about 3 millimeters wide. They are broadest at the base, whence they are abruptly narrowed below and gradually above to what appears to be a short callous point. The leaf substance is so well preserved that a whole leaf may be separated from the matrix, and when it is mounted in glycerine or Canada balsam the details of its cell structure can be studied under a compound microscope almost as well as those in a living leaf. The under side of the leaf shows a rather strong midrib, and on either side of it a broad band on which the stomata are borne. Altogether there are about 25 longitudinal rows of stomata, each with two large guard cells. The bands containing the stomata are darker in color than the remainder of the leaf, but whether the rows of stomata are in grooves could not be made out with certainty. The cells outside the bands of stomata are rectangular and mainly about twice as long as they are broad.

The genus *Tumion* of Rafinesque (*Torreya* of Arnott) comprises four species, two of which are American and two are natives of Japan and China. Of the American species, *Tumion taxifolium* Greene is found only in a very small area along Apalachicola River in Florida and *Tumion californicum* Greene is pretty well distributed over the State of California, being most abundant and of the largest size in the northern Coast Ranges. The California species is a tree from 50 to 70 or occasionally 100 feet in height and from 1 to 2 or exceptionally 4 feet in diameter.

[10] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 159, pl. 5, fig. 1, 1920.

The fossil species from Spokane appears to be nearest to *Tumion californicum*, from which it differs in its much smaller leaves, with broader stomatiferous bands. Otherwise the general appearance is much the same in both.

Six nominal fossil species of *Tumion* from North America have been described, all from Cretaceous rocks. The two species (*Torreya falcatum* and *T. virginicum*) from the Patuxent formation of Virginia described by Fontaine [11] are very doubtfully allocated to *Tumion*—in fact, they are quite different from the living species. *Tumion oblanceolatum* Lesquereux,[12] from the Dakota of Colorado, with the leaves attached by their whole base and thence decurrent down the branchlet, is also doubtfully referred to this genus, and the two species described by Dawson [13] (*Tumion densifolium* and *T. dicksonioides*), from the Upper Cretaceous of Alberta, are even more remote from the living *Tumion*. Dawson's species are said by Lesquereux to resemble certain of Heer's species from the Cretaceous of Greenland, but even so it is evident that all are greatly in need of revision.

The form from the Spokane area here described is clearly more closely related to the living forms than any previously described from this country—in fact, it hardly differs except in size from the living *Tumion californicum*.

This species is named in honor of Prof. T. A. Bonser, curator of the Public Museum of Spokane, who not only submitted the type specimen but has been especially generous in supplying material and information for this study.

Occurrence: Latah formation, Spokane, Wash., collected by T. A. Bonser.

Subfamily ABIETINEAE

Pinus sp.

Plate VIII, Figure 9

Leaves in clusters of three, the sheath deciduous; leaves more than 4.5 centimeters in length, about 1 millimeter wide, each with a faintly indicated median nerve or midrib.

I have hesitated to give this form a new specific name, as it is the only specimen of a pine that is present in the collections, and proper characterization of a species on such meager data is difficult. So far as can be made out the sheath at the base of the cluster of leaves is absent, and hence it is believed to belong to the group of so-called white or soft pines. Most of the American species belonging to this section of the genus have the leaves in clusters of five, but there is a small group of species in which the leaves are in one to four leaved clusters, and there is also a single North American species (*Pinus chihuahuana* Engelmann) belonging to the pitch or hard pines, which has the sheath deciduous and the leaves in threes.

This cluster of leaves from the Spokane area is similar to *Pinus knowltoni* Chaney, [14] from the Eagle Creek formation of Multnomah County, Oreg., and may indeed be identical with it. The description given by Chaney agrees very well with the specimen in hand, though he says nothing about the sheath. The figure of *Pinus knowltoni* showing the leaves is so obscure that nothing can be made out of it, and it is impossible to compare it with the Spokane specimen. Nothing like the staminate cones has been noted in the Spokane material.

Occurrence: Latah formation, well near Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922.

Subfamily TAXODIEAE

Sequoia langsdorfii (Brongniart) Heer

Plate IX, Figures 3–6

Sequoia lan sdorfii Brongniart) Heer, Flora tertiaria Helvetiae, vol. 1, p. 54, pl. 20, fig. 2; pl. 21, fig. 4, 1855.
Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 240, pl. 50, figs. 2–4, 1883.
Knowlton, U. S. Geol. Survey Bull. 204, p. 25, 1902.

Sequoia langsdorfii has almost as wide a distribution, both vertical and areal, as *Taxodium dubium* (*T. distichum miocenum*), and as with that species it seems more than possible that several forms of this type have been confused, as otherwise considerable variation must be accounted for.

This form is fairly abundant in the Spokane area and, as may be seen from the figures, agrees with the usual figures of this species. One specimen (fig. 5) has the male aments at the tip of the branchlet and hardly emergent from the apical leaves. This proves conclusively that it is a *Sequoia* and not a *Taxodium*, with which it is associated.

The branchlet shown in Figure 4 is quite similar to the lower portion of the branchlet figured by Lesquereux [15] from the auriferous gravels of California under the name *Sequoia angustifolia* and should perhaps be identified with that form, though it seems improbable that two species so closely allied as these seem to be should occur in the same beds. The other specimens here figured are certainly not to be distinguished from Lesquereux's figures of *Sequoia langsdorfii* from the John Day Basin.[16]

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust,

[11] Fontaine, W. M., U. S. Geol. Survey Mon. 15, pp. 234, 235, pl. 109, fig. 8; pl. 113, fig. 4, 1889.

[12] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 30, pl. 1, fig. 2, 1883.

[13] Dawson, J. W., Roy. Soc. Canada Trans., vol. 1, pp. 21, 25, pl. 2, fig. 4; pl. 5, figs. 20, 20a, 1882.

[14] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 160, pl. 5, figs. 3, 4, 1920.

[15] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 252, pl. 58, fig. 3, 1883.

[16] Idem, pl. 50, figs. 2, 3.

July, 1920; west bank of Deep Creek half a mile above mouth, northwest of Spokane, Wash., cut 1 mile west of Shelly Lake, about 10 miles east of Spokane, and well at Mica, 10 miles southeast of Spokane, collected by Henry Fair and C. E. Fernquist, 1922.

Sequoia? sp.

The material from the Spokane area submitted by T. A. Bonser and Thomas Large includes two lots of fossil wood. One is a solid block about 7 centimeters long and nearly 6 centimeters in diameter and was cut from a log about 15 feet long and 2 or 3 feet in diameter found at Division Street and the Spokane International Railway, in the city of Spokane. It was found in a pocket of clay, sand, and gravel between two lava flows. The other material consists of several fragments brought up from shale interbedded with lava 400 feet below the surface in a deep well at the State Custodial School near Medical Lake, southwest of Spokane.

The specimen from the large log is dark brown, almost black, and heavy and has apparently undergone considerable mineralization; the other specimens are light brown and show little or no evidence of infiltrating minerals.

No thin sections of these specimens have been cut, and the identification must be considered tentative, though so far as can be judged from examination with a low-powered microscope the structure is that of *Sequoia*.

Occurrence: Latah formation, between lava flows at Division Street and the Spokane International Railway, Spokane, Wash., from a log 15 feet long and 2 to 3 feet in diameter, collected in 1909 and submitted by T. A. Bonser; small fragments from depth of 400 feet in well at State Custodial School, Medical Lake, 20 miles southwest of Spokane, collected by Thomas Large, 1922

Taxodium dubium (Sternberg) Heer

Plate IX, Figures 2, 7–9; Plate X, Figure 2

Taxodium dubium (Sternberg) Heer, Flora tertiaria Helvetiae, vol. 1, p. 49, pl. 17, figs. 3, 15, 1855.
Berry, U. S. Geol. Survey Prof. Paper 91, p. 171, pl. 15, figs. 4–16, 1916.

Taxodium distichum miocenum Heer, Miocene baltische Flora, p. 18, pl. 2, pl. 3, figs. 6, 7, 1869.
Newberry, U. S. Geol. Survey Mon. 35, p. 22, pl. 47, fig. 6; pl. 51, fig. 3; pl. 52, figs. 2, 3; pl. 55, fig. 5, 1898.
Knowlton, U. S. Geol. Survey Bull. 204, p. 27, 1902; Alaska, vol. 4, p. 152, Harriman Alaska Expedition, 1904; Washington Acad. Sci. Proc., vol. 11, pp. 204, 207, 1909.
Penhallow, North American gymnosperms, p. 217, 1907; Report on Tertiary plants of British Columbia, p. 91, 1908.

The plant here designated *Taxodium dubium* is by far the most abundant species in the collections, occurring literally in hundreds. They are practically all detached branchlets with only a few detached leaves. There is a considerable range in the length and shape of the leaves, but they agree in a number of essential particulars. Most of the branchlets are slender, with a number of thin longitudinal lines or ridges. The leaves are attached at points all around the branch but by torsion at the base they are disposed in a two-ranked flat spray. The leaves are rather narrow, 1.5 to 2.5 centimeters long, obtusely pointed at the apex, and contracted at the base to a very short petiole or almost sessile. The leaves are not decurrent, though there is a line running down the branchlets for a short distance. They have a very distinct midrib.

The propriety of referring these branchlets to *Taxodium dubium* may be discussed. Under the name *Taxodium distichum miocenum* or occasionally as *Taxodium dubium*, branchlets of this type have been identified from a great number of localities throughout the Northern Hemisphere ranging in age from lower Eocene to Pleistocene and thence through many Pleistocene deposits to the living bald cypress of the coastal swamps of the Eastern and Gulf States. To judge by the figures given by the several authors there is a considerable variation in size and appearance, and it may be that more than one species has been confused, but as it is impossible without an adequate series of specimens to determine the specific limits, the species may be taken as a type of tree that had this wonderful geologic and geographic distribution. The specimens from the Spokane area agree well with many of the figures from both European and American localities, and there is no doubt that they can properly be classed with *Taxodium dubium*. They are also very much like some of the smaller examples of *Taxodium tinajorum* Heer,[17] from the Kenai formation of Alaska and the Miocene of Spitzbergen.

In 1872 Lesquereux [18] described some coniferous branchlets from Elko, Nev., under the name *Sequoia angustifolia*. This species was figured in 1878 in his "Tertiary flora" [19] and characterized as follows:

> Branches short, slender; leaves at unequal distances, sometimes very close, two or three together, or very distant, often dimorphous, linear-lanceolate, taper-pointed, open or curved backward, decurrent; middle nerve indistinct.

To this description he added the following comment:

> This form, though very variable, preserves its peculiar characters: the narrow, lanceolate, acute leaves, decurrent but not narrowed at base, with thin scarcely distinguishable middle nerve.

Unfortunately only one of the figured types of *Sequoia angustifolia* ("Tertiary flora," pl. 7, fig. 6) is preserved in the United States National Museum, and as this happens to be the smallest and least perfectly

[17] Heer, Oswald, Flora fossilis alaskana, p. 22, pl. 1, figs. 1–5, 1869.
[18] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 372, 1873.
[19] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 77, pl. 7, figs. 6–10, 1878.

preserved one, Lesquereux's diagnosis can not be confirmed.

A few years later Lesquereux [20] identified his *Sequoia angustifolia* from the auriferous gravels at Corral Hallow, Calif., and gave a single figure, and in 1902 I admitted a specimen from the Mascall formation in my "Flora of the John Day Basin,"[21] largely on the basis of its resemblance to the specimen from California.

I have a large number of specimens of coniferous branchlets recently collected at Elko, Nev., and they do not agree at all with Lesquereux's diagnosis and figures of his *Sequouia angustifolia.* One of the Elko specimens has been figured for comparison (Pl. IX, fig. 7), and from this it will be noted that the leaves are irregular and open or spreading, are obtuse at the apex instead of acuminate, and are distinctly contracted at the base and have a very distinct midrib. This form is distinctly a *Taxodium* and not a *Sequoia.* If the diagnosis and type figures of *Sequoia angustifolia* are correct, it obviously can not be the form that is now so well known from Elko.

Although the specimens of *Taxodium dubim* are so abundant in the present collections, only one example in the flowering state has been noted. This is shown on Plate IX, Figure 5, and is clearly the staminate inflorescence of a *Taxodium* and in all probability belongs with this species, but as there is no absolute connection between them, it has been figured without specific designation.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920 (Pl. IX, fig. 8); Deep Creek half a mile above mouth, northwest of Spokane, Wash. (Pl. IX, fig. 2), and cut 1 mile west of Shelly Lake, 10 miles east of Spokane, collected by Henry Fair and C. E. Fernquist, 1922; cut along Spokane, Portland & Seattle Railway, Spokane (Pl. IX, fig. 9; Pl. X, fig. 2), collected by T. A. Bonser.

Taxodium, male aments

Plate X, Figure 4

Among the several hundred coniferous branchlets the one here figured is the only one showing organs of reproduction. These are undoubtedly the staminate flowers of a *Taxodium* and probably belonged to the species here designated *Taxodium dubium.* They agree perfectly with those from the Mascall formation figured under the same caption in my "Flora of the John Day Basin." [22]

Occurrence: Latah formation, Deep Creek half a mile above mouth, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

[20] Lesquereux, Leo, U. S. Geol. Survey Terr, Rept., vol. 8 (Cretaceous and Tertiary floras), p. 240, pl. 50, fig. 5, 1883.

[21] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 24, 1902.

[22] Idem, p. 27, pl. 1, figs. 4 6.

Subfamily CUPRESSINEAE

Libocedrus praedecurrens Knowlton, n. sp.

Plate VIII, Figure 8

Similar to the living *Libocedrus decurrens* Torrey but more robust, the branches and branchlets nearly twice as thick as in the ordinary living specimens.

The little fragment figured is all that has been found of this form. It is small to serve as the basis of a supposed new species, and this assignment must be considered tentative and must await more complete material before it can be positively settled.

The incense cedar (*Libocedrus decurrens* Torrey) is found in the mountains of southern Oregon, the Sierra Nevada and Coast Ranges of California, the western edge of Nevada, and northern Lower California. It is a tree from 75 to 100 feet high and is 2½ to 4 feet (exceptionally 5 or 6 feet) in diameter. According to Sudworth it attains an age of some 500 to 700 years. It does not now live within some hundreds of miles of the Spokane area, but if the fragment here figured is correctly identified, the immediate forerunner of the species existed in Miocene time far to the north of its present habitat.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and submitted by the Spokane Public Museum.

Class ANGIOSPERMAE

Subclass MONOCOTYLEDONES

Order PANDANALES

Family TYPHACEAE

Typha? sp.

Plate IX, Figure 11

The collection made by R. W. Chaney in the Spokane area includes a single fragment of a monocotyledonous leaf. It was evidently a long, narrow, cattail-like leaf about 1 centimeter wide and has parallel veins of three degrees. The major nerves are strong and are about 1.5 millimeter apart. Between these are three less strong veins, and between these one to three very fine veins. The cross veins are usually between the veins of the second degree, though here and there a cross vein may pass over two of the second-rate parallel veins.

This fragment is so small that it is possible only to characterize it in a general way. It appears to be a leaf of *Typha*, but as this is not certain the reference to *Typha* has been questioned. It simply serves to direct attention to the fact that a plant of this type was present.

Occurrence: Latah formation, Spokane, Wash., collected by R. W. Chaney, July, 1921, specimen in the University of California, No. $\frac{3940}{22843}$.

Order NAIADALES

Family POTAMOGETONACEAE

Potamogeton sp.

Plate X, Figures 5, 6

This appears to be a fragment of the basal portion of a thin, pellucid, grasslike submerged leaf of *Potamogeton*. It is narrowly linear, narrowed below to a long wedge-shaped point of attachment, and of unknown shape above. There is a fairly strong midvein, and on each side of it there are three or four very thin, somewhat irregular veins, connected by more or less irregular cross veins.

As nearly as I may judge from so small a fragment it appears to resemble most closely the submerged leaves of the living *Potamogeton heterophyllus* Schreber. This is a highly variable species, occurring in different forms throughout almost all of North America except the extreme north and also in Europe. Its submerged leaves are linear-lanceolate, from 1 to 6 or 7 inches long and 1 to 8 lines wide.

As this flora was deposited in ponds or slow-moving streams it is reasonable to suppose that the habitat would be congenial for *Potamogeton*—in fact, it is surprising that there is not more evidence of the presence of this genus.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Order GRAMINALES

Grass, leaf

Plate X, Figure 7

The small specimen here figured is of little value except to indicate the undoubted presence of this group of plants. It is a fragment of the apical portion of a leaf about 5 centimeters long and 2.5 millimeters wide. It is deeply channeled in the middle.

Specimens that are little if any better preserved than this have received both generic and specific names, but there is hardly one chance in a thousand that such a form could be correctly allocated or identified subsequently.

Occurrence: Latah formation, cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash., collected by Kirk Bryan, June, 1923.

Grass?, genus?

Plate X, Figures 8, 9

This small and rather obscurely preserved specimen appears to be a small, creeping grass. The basal part apparently consists of a radicle from which two or three rhizomes arise. These rhizomes were apparently procumbent or creeping, with short, erect, compact, leafy or scaly branches.

Dr. Arthur Hollick has been kind enough to compare this specimen with living material in the herbarium of the New York Botanical Garden, especially in those genera of grasses with creeping stems, such as *Eragrostis*, *Syntherisma*, *Dactyloctenium*, *Elusine*, and *Capriola*, and although there is a general resemblance it is not sufficiently close to warrant even a generic identification. This specimen seems most like a grass and has been figured in the hope that someone may be able to place it.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, April, 1922.

Order ARALES

Family ARACEAE

Arisaema hesperia Knowlton, n. sp.

Plate X, Figure 1

The material from the Spokane area includes the single specimen of this plant that is here figured. It is a globose head of fruits or "berries" borne on a long, naked peduncle. The head is about 2 centimeters in diameter and bears a number (nine are shown in the side view of the specimen) of globose fruits or berries that are about 4 millimeters in diameter. The surface of these berries is more or less corrugated or irregularly wrinkled, as if they had been fleshy or had had a fleshy covering with perhaps a hard "stone" beneath. Of the supporting organ or peduncle 3.5 centimeters is preserved, but it was longer than this, as it runs off the matrix without evidence of attachment. It is slightly more than 2 millimeters broad and is striate or wrinkled longitudinally, a feature which indicates that it was fleshy.

So far as I am able to determine this specimen is closely similar to the fruit of the living *Arisaema triphyllum* (Linné) Torrey, the Indian turnip of the eastern United States, which ranges from Nova Scotia to Florida and west to Ontario, Minnesota, Kansas, and Louisiana, delighting especially in moist woods and thickets. The fossil form has a longer, more uniform-sized peduncle than the living species. the head is globose rather than ovoid, and the berries are apparently wrinkled instead of being smooth and shining. Whether these differences are sufficient to warrant a generic separation seems doubtful, and if the form is correctly interpreted, as it seems to be, the presence of the genus in this flora is placed on a secure footing.

Two other fossil species from this country have been described under the name *Arisaema*—namely, *Arisaema cretacea* Lesquereux, from the Dakota sandstone of Kansas and the Magothy formation of Cliffwood, N. J., and *Arisaema? mattawanense* Hollick, also from the Magothy formation at Cliffwood, N. J.

85658°—26——3

However, both these are based on portions thought to represent the spathe and can not be compared with the present specimen, quite aside from the marked difference in age. The genus has not been reported in a fossil state outside of the United States. No other portion that can be referred to *Arisaema* has been found in the Spokane area.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Subclass DICTOTYLEDONES

Order SALICALES

Family SALICACEAE

Populus heteromorpha Knowlton, n. sp.

Plate XII, Figures 8–10; Plate XIII, Figures 1–7; Plate XIV, Figures 1–3; Plate XV, Figures 3–5

This form is represented by approximately 200 specimens, and it is without exception one of the most polymorphous species that I have ever studied. If it were not for connecting forms it would be easy to select a number that are seemingly so distinct as to merit specific separation, but when the specimens are viewed as a whole it seems impossible to draw any definite lines. From the carbonaceous substance that is still present in many specimens it is evident that the leaves were rather thick and coriaceous. They had a fairly stout petiole about 2.5 centimeters in length. In perhaps a majority of the specimens the leaves are ovate or ovate-elliptical, with a rounded or very obtusely wedge-shaped or nearly truncate base. They are all more or less obtuse, and some of them are rounded at the apex. From the ovate form there is variation in two directions. In one, shown in Plate XII, Figure 10, the apical portion is proportionally more elongated, a form reached through the forms shown in Plate XIII, Figure 6, and Plate XIV, Figure 2. In the other type the apical portion is short and obtuse, and the basal portion is expanded until the outline is almost circular or even reniform, as shown in Plate XIII, Figures 2 and 5, and Plate XV, Figure 3.

In the configuration of the margin there is considerable variation. In the smallest leaf noted, which is only 2 centimeters long and 1.75 centimeters broad, shown in Plate XII, Figure 9, the margin is slightly undulate. In the leaf shown in Plate XII, Figure 8, it is entire except for two slight basal lobes. A few of the large leaves have a similar marginal outline, as shown in Plate XV, Figure 5; or, as shown in Plate XIII, Figure 2, there may be two small lobes on each side. In some of the broader forms the effect is to become three-lobed with perhaps undulations or slight minor lobes.

The principal nervation in these leaves is essentially the same—three-ribbed from the top of the petiole. The midrib is slightly larger than the ribs and has usually three or four pairs of secondaries in the upper portion, these curving upward and arching near the border. The lateral ribs are usually much curved and pass upward for varying distances, some of them nearly or quite reaching the apex, others joining the lowest pair of secondaries on the midrib. In the very broad leaves these ribs may reach up for only half the length of the blade. They have several branches on the outside which arch near the margin, some of them with two or three series of loops. The nervilles are numerous, thin, and nearly always broken. The finer nervation forms irregularly quandrangular areas.

This species does not appear to be very closely similar to any living North American form, but it is suggestive of *Populus alba* Linné and *Populus canescens* Smith, of western and southern Europe. In diversity of form it is especially like *Populus alba*, which has leaves ranging from ovate or elliptical to markedly three-lobed with variously toothed margins. The primary nervation in *P. alba* shows three ribs from the top of the petiole, but the lateral ribs do not ascend so high as they do in many of the leaves of *Populus heteromorpha*.

Certain fossil American species, however, show strong points of agreement with the leaves of *P. heteromorpha*. These are leaves of the type of *Populus arctica* Heer, which are so abundant in the Arctic Eocene and especially in the Fort Union formation. In these the lateral ribs arch around and terminate in or near the apex of the blade. This feature, as already pointed out, is to be noted in the leaves under consideration, but it is not so marked as in *Populus arctica* and its more or less close relatives. It seems possible that the leaves of *P. heteromorpha* are showing a transition from the three-ribbed *arctica* type to the pinnate-veined leaves of most modern forms. It is held by some students that the forms of the *arctica* type are not properly referred to *Populus*—that they represent, for instance, archaic survivals from the Trochodendraceae—but if the above interpretation is correct there may be an actual transition between the palmately ribbed Eocene types and the modern pinnate types.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Populus fairii Knowlton, n. sp.

Plate XV, Figure 2; Plate XVI, Figures 1–3

Leaves evidently coriaceous, large (8 to 12 centimeters broad, 6.5 to 8 or 9 centimeters long), from nearly circular to very broadly ovate, truncate, or slightly heart-shaped at the base, obtuse and rounded at the apex; margin entire below, with three or four large, obtuse lobes on each side separated by shallow sinuses; petiole stout, at least 4 centimeters long; nervation palmately five-ribbed from the top of the petiole; midrib with two or three pairs of thin, alternate, often irregular secondaries above the middle of the blade, which arch around nearly or quite to the midrib in the upper part; lateral ribs nearly as strong as the midrib, arising at an angle of 40° or 50°, much curved upward and joining the lowest pair of secondaries on the midrib, each with several tertiary branches on the outside, these mainly arching around and each joining the one next above; lowest pair of ribs (these are virtually basal secondaries on the lateral ribs which arise with the ribs at the top of the petiole) thin, usually at right angles to the midrib, occasionally stronger (as shown in Pl. XVI, fig. 3), nearly as strong as the other pair of ribs; nervilles thin, broken, breaking up into the finer quadrangular areolations.

This form is represented by five leaves, four of which are figured. They were found in association with the numerous leaves of *Populus heteromorpha*, and it is possible that they should be referred to that species, but they are so very much larger and show so strongly marked a tendency toward five ribs instead of three that it hardly seems as if they could be that species, especially as there are no intermediate forms. They are certainly closely related to *P. heteromorpha*, however, and subsequent collections may show them to intergrade in size and nervation.

I take pleasure in naming this species in honor of Mr. Henry Fair, of Spokane, Wash., who assisted in collecting these and many other excellent specimens.

Occurrence: Latah formation, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, March, 1922.

Populus lindgreni Knowlton

Plate XIV, Figures 4–7

Populus lindgreni Knowlton, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 725, pl. 100, fig. 3, 1898; U. S. Geol. Survey Bull. 204, p. 29, pl. 2, fig. 1, 1902.

The type of this species came from the Payette formation near Marsh post office (now Montour), Boise County, Idaho. A single example was subsequently found in the Mascall formation of the John Day Basin, Oreg. The material from Coeur d'Alene includes four finely preserved leaves, all of which have been figured, as well as several less perfect specimens. These specimens permit a revision or amplification of the description. In the type specimen there are five ribs that arise at the top of the petiole, the second pair being by far the stronger. In the new specimens there are three principal ribs, the lateral ones with several secondary branches on the outside. In some specimens the first pair of secondaries arise from the ribs at or near the base, thus appearing to be five-ribbed, but in most specimens the first secondaries arise a short distance above the base. The lowest pair of secondaries in the broader leaves have several tertiary branches that supply the lower portion of the blade. Many of the upper secondaries on the midrib as well as the lateral ribs and the secondary and tertiary branches from them are forked, the ultimate branches ending in the marginal teeth. The nervilles are strong, mainly broken and irregular, some of them not reaching across the space between the major nervation.

It is now evident that there is a considerable range in size and in the shape of the base of this species. The smallest leaf found (fig. 7) is 4.5 centimeters long and 4.5 centimeters wide; it has the petiole preserved for a length of 1.5 centimeters. The next in size (fig. 5) is a little more than 6 centimeters long and is 7 centimeters broad. The one shown in Figure 4 is about 6.75 centimeters wide and 6.5 centimeters long. The largest specimen (fig. 6) is fully 8 centimeters broad and nearly 8 centimeters long.

It will be seen that two of the specimens figured are practically truncate at the base, but a third (fig. 5) is slightly and the fourth (fig. 6) markedly heart-shaped at the base. In all the specimens the margin is finely and evenly undulate-toothed. In one of the specimens (fig. 5) there is a slight lobe on one side in which the lateral rib terminates.

Among living forms this appears to approach most closely the European *Populus tremula* or its American relative *P. tremuloides* Michaux, especially in marginal dentation, but they differ considerably in shape.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Populus washingtonensis Knowlton, n. sp.

Plate XV, Figure 1

Leaf thick and coriaceous, nearly circular, broadly truncate at the base and rounded obtuse at the apex; margin with few large, low, rounded lobes; petiole very stout, probably flattened; nervation pinnate, the midrib straight, very thick below, thin above, with about five pairs of strong, opposite, parallel secondaries, the lowest pair arising at the top of the petiole and thus simulating a three-ribbed appearance; the lowest pair of secondaries with three or four tertiary branches and the middle secondaries with two or three branches, which terminate in the margin; nervilles rather sparse, mainly broken; finer nervation not well retained.

This species is represented only by the specimen figured. It is about 6.5 centimeters long and nearly 8 centimeters wide; the petiole is 2.5 centimeters long and was either flattened or was thick and fleshly and has been crushed flat. It is fully twice the thickness of the base of the midrib.

This leaf was found in association with leaves of *Populus lindgreni* and may be an extreme form of it, but the differences are so many and so marked that the leaves must seemingly be separated. Thus in place of the evenly and finely undulate-toothed margin of *P. lindgreni* we have the few large rounded lobes with entire margins in *P. washingtonensis*. The nervation in *P. washingtonensis* is more strict and more obviously pinnate than it is in *P. lindgreni*, and the petiole is obviously stouter.

The margin in *P. washingtonensis* is most like the margin of the living *P. grandidentata* Michaux; the shape of the leaf is different. It does not approach very closely any fossil form described from the region.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Salix elongata O. Weber

Plate XII, Figure 4

Salix elongata O. Weber, Palaeontographica, vol. 2, p. 177, pl. 19, fig. 10, 1852.
Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 169, pl. 22, figs. 6, 7, 1878.
Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, p. 698, 1899.

The leaf here figured, which is absolutely perfect, appears to be the same as specimens from Elko, Nev., identified by Lesquereux as *Salix elongata* O. Weber. Whether or not they are correctly referred to the European species is a question that need not be answered at this time.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Salix perplexa Knowlton

Plate XII, Figure 5

Salix perplexa Knowlton, U. S. Geol. Survey Bull. 204, p. 31, pl. 2, figs. 5–8, 1902.
Chaney, Am. Jour. Sci., 5th ser., vol. 4, p. 216, 1922.

The specimen figured agrees well with one of the figured types of this somewhat variable species. This species is very abundant in the Mascall formation of the John Day Basin, and recently Chaney has found it in the Payette formation of western Idaho.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Salix dayana Knowlton

Plate XII, Figures 1, 2

Salix dayana Knowlton, U. S. Geol. Survey Bull. 204, p. 31, pl. 2, figs. 9, 10, 1902.

There are several specimens that appear to belong to this species. Of the two examples illustrated the one seen in Figure 1 is the under side of the leaf, showing the finely reticulated ultimate nervation. The other (fig. 2) shows the upper side of the leaf and the disposition of the secondaries.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Salix remotidens Knowlton, n. sp.

Plate XII, Figure 7

Leaf of finer texture, lanceolate, 11 centimeters long, 2.7 centimeters wide, broadest below the middle, thence tapering to the obtuse base and above to a long, slenderly acuminate apex; margin entire for the lower and upper thirds of the blade, the middle third with a few very small, blunt teeth; petiole stout, 1.5 centimeters long; midrib moderately strong for the size of the blade, straight; secondaries 12 or 15 pairs, thin, mainly alternate, the basal pair opposite, at an angle of about 45°, the others nearly at a right angle, all much curved upward and running for a considerable distance near the margin; in the lower and middle portions of the blade there are a few intermediate secondaries; finer nervation obscure.

This leaf appears to be very well characterized by the few, blunt teeth in the middle of the blade, but in size, shape, and nervation it is so characteristically a willow leaf that it would be difficult to diagnose it so that it could be readily distinguished from numerous others.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Salix inquirenda Knowlton, n. sp.

Plate XI, Figures 1, 2

Leaves firm in texture, large, lanceolate-acuminate, rather abruptly rounded at base, long and slenderly acuminate at apex; margin evenly toothed throughout, even near the base, the teeth rather remote, some of them fairly sharp but most of them blunt and rounded; midrib very strong below, very thin above; secondaries numerous, arising at a low angle, some of them almost at a right angle, then curving upward along the borders and often each joining the one next above and sending thin branches, almost nervilles, to the teeth; intermediate secondaries between most of the secondaries, especially in the lower and middle portions of the blade; finer nervation producing a fine irregular network.

This species is represented by several more or less perfect leaves, three of which are figured. The largest leaf (fig. 2) is nearly 3 centimeters wide and has the base well preserved. The others (fig. 1) lack the base but have the apex almost complete. The lower of these two, preserved on the same piece of matrix, is about 13 centimeters long and 2.25 centimeters wide. The upper one was at least 12 centimeters long and is nearly 2.5 centimeters wide.

In size, shape, and nervation these leaves are so characteristic of *Salix* that the generic reference can be considered settled, but decision as to the species is quite another matter. Many living species can not be separated by the leaves alone, and many fossil species are equally difficult to characterize.

Of the several forms of willow leaves described in the present paper the species that seems to be nearest to the leaves under discussion is *Salix remotidens*, which has the few remote, blunt teeth confined to the middle of the margin, whereas in these the teeth are present throughout, although of much the same character. Among described species the leaves under discussion are very similar in size, shape, and nervation to some of the leaves from the Swiss Miocene, described and figured by Heer [23] under the name *Salix varians* Göppert, but they differ in the character of the teeth.

Salix varians Göppert is accepted as present in the Mascall formation, as well as in the beds at Ellensburg, Wash., the Miocene of the Yellowstone National Park, and supposedly in the Kenai formation of Alaska.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

Salix bryani Knowlton, n. sp.

Plate XII, Figure 6

Leaf firm in texture, rather narrowly lanceolate, apparently acuminate at both base and apex, though these parts are missing; margin with very small, remote, sharp, appressed teeth; midrib very strong, especially below; secondaries numerous, probably 15 or more pairs, alternate, at a low, almost right angle in the lower part, at an angle of about 30° in the middle and upper part of the blade, all camptodrome, each curving and joining the one next above, forming an intramarginal "stitch"; finer nervation forming a close network of irregularly quadrangular areas.

The leaf figured must have been about 8 centimeters in length when perfect and is 1.5 centimeters wide near the middle, whence it narrows in about equal degree to base and apex. The secondary nervation is characteristically that of *Salix*.

This leaf, as regards size and shape, belongs to the nondescript type that is very hard to characterize, but the peculiar type of marginal teeth is unusual and should make it easy to recognize in future. The living *Salix discolor* Muehlenberg has teeth of this kind.

Occurrence: Latah formation, cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash., collected by Kirk Bryan, June, 1923.

Salix sp.

Plate XII, Figure 3

In the collection from Coeur d'Alene I find this little leaf, which appears to be different from any of the other *Salix* leaves. It was evidently rather thin in texture, lanceolate, with an apparently rounded base and probably acute apex. It was 5 centimeters in length and nearly 1.5 centimeters in width. The margin is entire and slightly undulate. The nervation is delicate, consisting of a thin, straight midrib and about 10 pairs of thin, alternate, camptodrome secondaries, which arch upward and each joins the one next above, often by several large loops. The finer nervation produces rather large irregular areolae.

This form could be compared with a number of described species, but the difficulty of establishing identity on a single incomplete leaf is so great that it has seemed best not to assign a specific name. If more complete leaves are found later it will be an easy matter to name them and characterize them more fully.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Order FAGALES

Family BETULACEAE

Alnus, pistillate cones

Plate XVIII, Figures 3–5a

The two specimens figured are undoubtedly the mature pistillate aments or "cones" of an *Alnus*. The shape and margins of the individual scales can not be made out with certainty, but the nutlets appear to be ovoid, though the presence or absence of a wing can not be determined.

Among living species these "cones" seem to resemble most closely those of *Alnus incana* (Linne) Willdenow, the hoary alder, a species widespread in northern North America as well as in Europe and Asia.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Betula fairii Knowlton, n. sp.

Plate XVII, Figure 4

Leaves small, about 23 millimeters long, 13 millimeters wide, apparently coriaceous, elliptical, about equally rounded to both base and apex; margin entire at the base, thence finely toothed, the teeth somewhat irregular, mainly sharp-pointed, the point indurated or thickened; nervation strong, especially the midrib; there is a thin pair of basal secondaries at right angles to the midrib, then about six pairs of alternate secondaries at an angle of 45°, straight and ending in the teeth; nervilles numerous, mainly percurrent and at right angles with the secondaries; finer nervation abundant, forming an irregularly quadrangular network.

This little leaf, the only one observed, is absolutely perfect, including the petiole. It may be known by its elliptical shape with obtuse and rounded apex and rounded, almost truncate base, irregularly toothed margin, and very strong nervation. It is most closely related to *Betula heteromorpha* Knowlton,[24]

[23] Heer, Oswald, Flora tertiaria Helvetiae, vol. 2, pl. 65, figs. 1-3, 6-16, 1856.

[24] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 39, pl. 3, figs. 6, 7, 1902.

from the upper part of the Clarno formation (Bridge Creek locality), from which it differs in its smaller size, elliptical shape with rounded and obtuse apex and more truncated base, and fewer secondaries.

This species is named in honor of Mr. Henry Fair, of Spokane, who not only collected the type specimen but has rendered invaluable aid in collecting throughout the Spokane area.

Occurrence: Latah formation, cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

Betula nanoides Knowlton, n. sp.

Plate XVIII, Figure 2

Leaves small, about 15 millimeters long and 12 millimeters broad, broadly ovate, abruptly rounded and slightly heart-shaped at base, almost equally rounded above to the acuminate apex; margin finely serrate, the teeth sharp-pointed, probably glandular tipped; midrib relatively very strong; secondaries six or seven pairs, the lowest pair nearly at right angles with the midrib, with tertiary branches on the lower side, other secondaries at an angle of about 40°, nearly straight, lower and middle ones with one or two branches, all craspedodrome and ending in the teeth; nervilles numerous, mainly at right angles to the secondaries, broken or percurrent.

This little leaf seems certainly referable to *Betula.* The margin is finely serrate, and in addition there is a faint indication of its being doubly serrate—that is, there are slight projections beyond the general outline where the secondaries and their branchlets enter the teeth, but they are of little prominence.

This species does not seem to approach very closely any living American birch, perhaps the nearest in shape being *Betula occidentalis* Hooker, but that species has leaves 7 or 8 centimeters long that are more acute at the apex. The European *Betula humilis* Schrank, however, is very similar both in size and shape. This is a small shrub from 3 to 6 feet high growing on peat bogs in the Tyrol and elsewhere in central Europe, but the leaves are less truncate at the base and have fewer and larger teeth, with no tendency to be doubly serrate.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Betula heteromorpha Knowlton

Plate XVII, Figures 5, 6

Betula heteromorpha Knowlton, U. S. Geol. Survey Bull. 204, p. 39, pl. 3, figs. 6, 7; pl. 5, fig. 1, 1902.

Several leaves were noted in the collections that must be referred to this species. Except for its slightly larger size the larger specimen here figured is not to be distinguished from the leaf figured on Plate V, Figure 1, of my "Flora of the John Day Basin," and the smaller one (fig. 5) is the same as Figures 6 and 7 of Plate III of that work.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920; cuts on Spokane, Portland & Seattle Railway and Chicago, Milwaukee & St. Paul Railway, Spokane, Wash., collected by R. W. Chaney, 1922. Specimen in University of California Museum, No. $\frac{3946}{22871}$.

Betula? largei Knowlton, n. sp.

Plate XVII, Figures 1, 2

Leaves large, 12 to 15 centimeters long, 6 to 8 centimeters wide, fairly firm in texture, elliptical or broadly ovate-elliptical, abruptly rounded below to a truncate or slightly heart-shaped base and above to an apparently acuminate apex; margin obscurely doubly serrate—that is, the teeth entered by the secondaries are slightly larger than the others, of which there are usually two or three between two of the larger ones; all are sharp-pointed; midrib thick, straight; secondaries 10 or 12 pairs, at an angle of 40°–50°, parallel, nearly straight, entering the larger teeth; nervilles rather sparse, mainly unbroken and at right angles to the secondaries, finer nervation producing a fine network between the nervilles.

This form is represented by several leaves, two of the best of which are figured. I am uncertain as to the generic reference. There is some resemblance to certain living leaves of *Alnus* and *Corylus,* but altogether they agree best with larger leaves of *Betula,* such as especially long, slightly heart-shaped leaves of *Betula papyrifera* Marshall. However, considering the uncertainty the generic reference has been questioned.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922; well at Mica, Wash., southeast of Spokane, collected by Thomas Large for J. T. Pardee, August, 1922.

Betula bryani Knowlton, n. sp.

Plate XVIII, Figure 1

Leaf thin, ovate-elliptical, abruptly rounded below to the slightly heart-shaped base, apparently acuminate at the apex; margin entire at the base, then strongly toothed, the teeth entered by the secondaries slightly larger than the two or three intermediate ones, all deltoid in shape; midrib strong; secondaries six pairs alternate, at an angle of about 45°, very little curved upward, craspedodrome, entering the larger teeth; nervilles numerous, mostly simple and at right angles to the secondaries; finer nervation producing a fine quadrangular network.

The little leaf figured is the only one noted in the collections. It is about 5.5 centimeters long and nearly 3.5 centimeters wide. It is not exactly doubly serrate, though there is a tendency for the teeth entered by the secondaries to be slightly larger than the intermediate ones. Among living species it seems to approach most closely certain of the broader, heart-shaped forms of *Betula papyrifera* Marshall, the well-known canoe or paper birch. The teeth, however, are not so sharp-pointed as in most living species of *Betula*. The species is named in honor of Mr. Bryan.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, 1923.

Betula thor Knowlton, n. sp.

Plate XVII, Figure 3

Leaf of medium size, about 6.5 centimeters long and 4 centimeters wide, with a petiole at least 2 centimeters long, membranaceous, ovate, very obtusely wedge-shaped at the base and acuminate at the apex; margin entire at base, then distinctly doubly serrate, the teeth sharp, pointing upward; petiole and midrib strong; secondaries eight or nine pairs, alternate, at an angle of about 40°, straight, parallel, ending in the larger teeth, and usually with two or three light branches which enter the smaller teeth; nervilles numerous, thin, irregular, mainly oblique to the secondaries; finer nervation producing an intricate, fine network.

Among living American species the present species appears to approach most closely certain of the narrower, more normal leaves of *Betula papyrifera* Marshall, the common paper birch, which ranges widely from Labrador, the southern shores of Hudson Bay, and Great Slave Lake westward to Montana and northwestern Washington, though not very abundant in the Rocky Mountains.

Among fossil species known from the general region *Betula thor* shows points of agreement with several. Thus, *Betula heteromorpha* Knowlton,[25] from the upper part of the Clarno formation at Bridge Creek, Oreg., agrees in size, but its marginal teeth are almost invariably rounded instead of sharp, and it is less obviously doubly serrate.

The species described above under the name *Betula bryani* is from the same locality as the present species, but it is distinctly heart-shaped at the base and has the teeth deltoid instead of sharp-pointed; it is also less obviously doubly serrate. If a series of leaves were available from this locality it might show these two forms to be the same, but as at present known they seem to be quite distinct. It may be that these correspond to the type and the variety *cordifolia* of *Betula papyrifera*.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, 1923.

[25] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 39, vol. 3, figs. 6, 7; pl. 5, fig. 1, 1902.

Carpinus sp.

This specimen is a fragment of what appears to be a leaf of *Carpinus*. It is a small leaf, apparently between 6 and 7 centimeters in length and a little over 2 centimeters in width. It is lanceolate, apparently long wedge-shaped at the base and narrowly acuminate at the apex. The margin is sharply doubly serrate, though the distinction between the major teeth, or those entered by the secondaries, and the intermediate teeth is not very pronounced. The number of secondaries can not be made out from this fragmentary specimen, but there must have been 10 or 12 pairs. They are close, parallel, at an angle of 45° or 50°, and nearly straight. The nervilles are numerous, rather strong, at right angles to the secondaries.

This specimen is so fragmentary that it can not be compared very successfully with other forms. It is nearest to the living *Carpinus carolinensis* Walter but is apparently longer and narrower. In some particulars it agrees with *Alnus carpinoides* Lesquereux,[26] from Bridge Creek, Oreg., but that is a much larger species and has the margin much more pronouncedly doubly serrate. The present specimen is also similar to certain of the smaller, narrower leaves of *Carpinus grandis* Unger, such for instance as some of those figured by Heer [27] from the Miocene of Sakhalin.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Castanea castaneaefolia (Unger) Knowlton

Plate XVIII, Figures 7, 8; Plate XIX, Figure 1

Castanea castaneaefolia (Unger) Knowlton, U. S. Geol. Survey Bull. 152, p. 60, 1898.

Castanea ungeri Heer. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 246, pl. 52, figs. 3–7, 1883.

These specimens agree with those previously reported from the John Day Basin, Oreg.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Quercus merriami Knowlton

Plate XIX, Figures 4, 5

Quercus merriami Knowlton, U. S. Geol. Survey Bull. 204, p. 49, pl. 6, figs. 6, 7; pl 7, figs. 4, 5, 1902.

Quercus pseudo-lyrata angustiloba Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 17, pl. 11, fig. 2, 1888.

The nearly perfect leaf figured is not to be distinguished from the smaller of the leaves figured among the types of *Quercus merriami* Knowlton, except that the teeth are not quite so sharp-pointed. The tip of a leaf shown in Figure 4 has the teeth bristle-

[26] Lesquereux, Leo, U. S. Geol. Survey Terr., vol. 8 (Cretaceous and Tertiary floras), p. 243, pl. 50, fig. 11; pl. 51, figs. 4, 5, 1883.

[27] Heer, Oswald, Flora fossilis arctica, vol. 5, Abt. 4, pl. 8, figs. 3, 4, 6; pl. 9, figs. 1, 2, 1878.

pointed, as in the types, though the teeth are not quite so large.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Quercus cognatus Knowlton, n. sp.

Plate XX, Figures 1–4; Plate XXI, Figures 1, 2

Leaves variable in size, coriaceous, lanceolate or elliptical-lanceolate, rather obtusely wedge-shaped at the base, moderately acute at the apex; margin entire for a short distance at the base, then provided with 6 to 10 large teeth separated by rounded sinuses; the lower teeth are the smaller and are usually rounded; the upper ones are the larger and usually sharp-pointed; petiole strong; midrib very strong; secondaries strong, straight, mainly alternate, as many as the teeth and entering them; nervilles numerous, strong, mainly broken, forming with the smaller veins a fine network.

This is one of the most abundant species in the collections, being represented by not less than 25 more or less perfect leaves. The largest specimen (Pl. XX, fig. 1) must have been at least 18 centimeters in length exclusive of the petiole, which is 1.5 centimeters long; its greatest width is 6.5 centimeters. The next size (Pl. XX, fig. 2) was probably about 13 or 14 centimeters long and only 4 centimeters wide. A nearly similar example (Pl. XXI, fig. 1) was 11 or 12 centimeters long and about 4.5 centimeters wide. This specimen, which has somewhat sharper lobes than those already mentioned, has a petiole 2.5 centimeters long. The one shown in Figure 1 of Plate XXI has all the lobes sharper pointed than the majority. Still another specimen was only about 10 centimeters long. Plate XX, Figure 3, shows the nearly complete apical portion.

At first it was presumed that these Spokane leaves could be referred to one of the forms of the polymorphous *Quercus pseudo-lyrata* Lesquereux, which is so abundant in the Mascall formation of the John Day Basin, but a careful comparison convinces me that they are not identical. Some of the Spokane leaves approach more closely what has been segregated as *Quercus merriami* Knowlton,[28] but that species differs so much that they can not be placed together.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920 (Pl. XX, fig. 3); Spokane, Wash.

Quercus cf. Q. pseudo-lyrata Lesquereux

Plate XXII, Figure 2

The specimen here figured, a mere fragment, is all that was noted of this form. It was a large leaf probably not less than 15 centimeters long and 8 or 9 centimeters wide. The margin is very deeply cut into probably three or four large, upward-pointing, rather acute lobes. The sinuses between the lobes are very deep and rounded. The nervation is preserved with remarkable fidelity and is well shown in the figure. The midrib is very strong and shows little diminution within the fragment present. The secondaries are also strong; they pass nearly straight well into the lobes and then turn slightly upward. The intermediate secondaries are numerous, at irregular distances, and of various sizes, all nearly at right angles with the midrib and camptodrome, arching for considerable distances just inside the margin, especially around the sinuses. The finer nervation is irregularly quadrangular.

This leaf is of the type of *Quercus lyrata* Walter and in fact may be a large leaf of *Quercus pseudolyrata* Lesquereux,[29] which is an abundant form in the Mascall formation of the John Day Basin. It would probably do no great violence to identify this leaf directly with Lesquereux's species, but as it is so fragmentary it seems best to question the determination.

Quercus pseudo-lyrata is probably more closely related to *Quercus velutina* Lamarck and *Quercus californica* Cooper; the latter is the largest and most abundant species of the valley of southwestern Oregon and of the Sierra Nevada.

Occurrence: Latah formation, 1 mile west of Shelley Lake, half a mile south of "Apple Way," and about 10 miles east of Spokane, Wash., collected by Henry Fair, October, 1922.

Quercus rustii Knowlton, n. sp.

Plate XXI, Figures 3, 4

Leaves evidently coriaceous, lanceolate, narrowed from a point near or above the middle to the long wedge-shaped base and prolonged above into a slender, acuminate apex; margin with three remote, rather small, sharp-pointed teeth on each side; the teeth are separated by long, shallow sinuses; petiole short, stout; midrib very strong for the lower half of the blade, thence greatly reduced; secondaries 10 or 12 pairs, at an angle of 60° or 70°, the lower ones curving along the margin, those in the middle and upper part remote, entering the teeth; finer nervation producing a fine quadrangular network.

The best preserved of these leaves (fig. 3) is 10 centimeters long and about 2.5 centimeters wide. The other one figured (fig. 4) was probably nearly 12 centimeters long and about 3.5 centimeters wide between the points of the largest teeth.

This species is probably most closely related to *Quercus payettensis* Knowlton but differs in the long wedge-shaped base, the fewer, remote teeth, and the slenderly acuminate apex. This species is also very similar to certain of the narrower leaves of *Quercus*

[28] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 49, pl. 6, figs. 6, 7; pl. 7, figs. 4, 5, 1902.

[29] Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, pl. 2, figs. 1, 2, 1878.

merriami Knowlton [30] but differs in having fewer and smaller lobes and in the peculiar wedge-shaped base.

The species is named in honor of Mr. H. J. Rust, who collected all of the splendid material from the Coeur d'Alene locality.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Quercus spokanensis Knowlton, n. sp.

Plate XIX, Figure 3

This form is represented by the single specimen figured, which is the upper portion of a leaf that is now about 8 centimeters long but must have been 12 centimeters or more when complete. It is 6 centimeters wide in the middle. It appears to have been elliptical or possibly slightly obovate-elliptical. The margin is almost undulate-toothed, or in any event the teeth are regular, obtuse or very obtusely pointed, and separated by shallow sinuses. The midrib is moderately strong, and the secondaries are regular, evenly spaced, alternate, and as many as the marginal teeth, which they enter. The finer nervation is irregularly quadrangular and distinctly quercoid in appearance.

This species is quite unlike any of the other oaks in the collections. It is of the type of a group of living species which includes *Quercus michauxii* Nuttall, *Q. prinus* Linné, *Q. acuminata* Sargent, and others.

Among fossil species this is very close to *Quercus cowlesi* Chaney,[31] from the Eagle Creek formation of Multnomah County, Oreg.—in fact, it may be identical with that species. However, *Quercus cowlesi* has fewer, less prominent teeth and fewer, less regular secondaries. A series of specimens might well enough show these comparatively slight differences breaking down.

Occurrence: Latah formation, cut along Spokane, Portland & Spokane Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Quercus payettensis Knowlton

Plate XXI, Figures 5–7

Quercus payettensis Knowlton, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 730, pl. 102, fig. 9, 1898.

This species was based on a leaf from the Payette formation of Idaho that lacks both base and apex but is well characterized by its lanceolate outline and large deltoid teeth. None of the nervation is preserved except the midrib and secondaries.

The collection from Coeur d'Alene, Idaho, includes several specimens that, though slightly larger, must be referred to *Quercus payettensis.* The best preserved example, shown in Figure 7, is nearly perfect. It is long wedge-shaped at the base and rather abruptly deltoid pointed at the apex. It is 7 centimeters long and about 2.5 centimeters wide. Another specimen (fig. 5) is also nearly perfect. It shows the wedge-shaped base with one or two very small teeth, and in the middle of the leaf are the strong teeth, one of which is distinctly spine-tipped. The other specimen figured (fig. 6) is a segment from the middle of a leaf that must have been at least 10 centimeters long; it is nearly 3.5 centimeters wide between the points of the lobes. This is precisely the same as the type, except for its larger size.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Quercus sp.

Plate XIX, Figure 7; Plate XXII, Figure 9

Leaves coriaceous, ovate or ovate-elliptical, very obtusely wedge-shaped at the base, obtusely pointed at the apex, with two or three large, obtusely acuminate lobes on each side; midrib strong, more or less irregular and zigzag; principal secondaries as many as the lobes, at a low angle, much curved upward toward the margin; intermediate secondaries numerous, at irregular distances and angles, curving upward and disappearing along the margin; nervilles numerous, strong, irregular, mainly broken; finer nervation strong, irregularly quadrangular.

The two figured specimens are referred to this form. The larger one (Pl. XIX, fig. 7) was probably 9 or 10 centimeters long and 7 centimeters wide between the largest lobes. The other specimen (Pl. XXII, fig. 7) is 8 centimeters long and 5 centimeters wide.

This species seems to be quite distinct from the other forms found in these beds, though it may possibly be represented by somewhat distorted or abnormal leaves of one of the common forms.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Quercus praenigra Knowlton, n. sp.

Plate XIX, Figure 6

Leaf coriaceous, narrowly obovate, broadest above the middle, whence it is gradually narrowed to an abruptly rounded base; margin perfectly entire; petiole very stout; midrib very strong; secondaries mainly alternate, thin, at irregular distances, arising at a low angle (about 20° or 25°), much curved upward along the margins; nervilles mainly oblique to the secondaries, broken and irregular, and forming with the finer nervation a complicated network.

The incomplete specimen figured is the only one noted in the collections. It probably lacks the upper

[30] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 49, pl. 6, figs. 6, 7, 1902.

[31] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 169, pl. 11, fig. 5, 1920.

third and when perfect was presumably about 14 centimeters long. It is about 4.5 centimeters wide at the point where it is broken, and the missing portion was probably 5 centimeters or slightly more in width. Only a short portion of the thick petiole is retained.

This leaf is quite distinct from the other oaks of the collection, but among living species it seems fairly close to *Quercus nigra* Linné, the water oak of the eastern and southern United States. It is somewhat more obtuse at the base but otherwise is very similar.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, 1920.

Quercus simulata Knowlton

Plate XXII, Figures 3, 4

Quercus simulata Knowlton, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 728, pl. 101, figs. 3, 4; pl. 102, figs. 1, 2, 1898;
Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 168, pl. 12, fig. 1, 1920.

This species is represented by several examples, two of which have been figured. These, it will be seen, agree perfectly with the entire-leaved specimens from the type locality—that is, the Payette formation of Marsh, Idaho. In the type specimens the finer nervation was not well preserved, but in the present specimens it is perfectly retained. It is well shown in Figure 4.

A poorly preserved leaf found in the Eagle Creek formation of the gorge of Columbia River, Oregon, has been identified as *Quercus simulata* by Chaney. It has more marginal teeth than any of the type specimens, and the details of nervation are missing.

Occurrence: Latah formation, Deep Creek half a mile above mouth and cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Quercus chaneyi Knowlton, n. sp.

Plate XXII, Figure 1

This interesting species is well represented by the little leaf figured, which fortunately is nearly perfect. It was evidently very thick and coriaceous and is narrowly lanceolate, being slightly broader at a point about one-fourth its length from the apex. It was about 9 centimeters long and 1.5 centimeters wide, with the petiole preserved for a length of 0.5 centimeters, but is evidently not complete. From the broadest point in the blade it narrows gradually above to what was apparently an obtusely acuminate apex and downward to a long, narrow basal portion. The margin is entire or slightly undulate for the lower two-thirds and thence with four or five teeth on each side, these low and rounded below but one or two sharp-pointed higher up. These teeth are so small that they are hardly perceptible to the naked eye, though they are plain enough under a glass. The midrib is very thick and strong and is perfectly straight, but the secondaries are thin and immersed in the leaf substance. The secondaries number about 12 pairs. They arise at an angle of 40° or 45° and are close together in the lower part of the blade but remote in the upper part. They curve upward for a long distance, each usually joining the one next above and sending a thin branch to one of the marginal teeth or slight swellings. The nervilles are inconspicuous, being immersed in the leaf substance; they are mainly percurrent. The finer nervation is peculiar in that it forms a complete network of small, equal-sized arms.

This leaf is probably correctly referred to *Quercus*. At first glance its shape might suggest a leaf of *Salix*, and the peculiar netlike finer nervation is very much like that of certain lauraceous types, such as *Persea*, but the thick substance of the leaf and the few, small marginal teeth point to *Quercus*. It appears to belong to the group of so-called live oaks, in which the old leaves persist until the spring of the next year. It is perhaps closest to *Quercus virginiana* Miller, though longer and narrower than most leaves of that species.

Among fossil American species *Quercus chaneyi* most closely resembles *Quercus simplex* Newberry,[32] from the upper part of the Clarno formation of the John Day Basin, Oreg., and it has also been reported[33] from the Raton formation of northeastern New Mexico and southeastern Colorado. It differs, however, in being longer and narrower, broadest above instead of below the middle, in the sparsely toothed instead of entire margins, and in the netlike, finer nervation.

I take pleasure in naming this species in honor of Dr. Ralph W. Chaney, of the Carnegie Institution of Washington, who collected a part of this Spokane material.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Quercus obtusa Knowlton, n. sp.

Plate XXII, Figure 8

Leaf small, about 5.5 centimeters long and 2 centimeters broad, coriaceous, obovate-lanceolate, broadest in the upper third, whence it rounds above to an obtuse apex and below to a long, regularly wedge-shaped base; margin entire except very near apex, where there are two or three small, sharp-pointed teeth; petiole very strong; midrib exceptionally strong, perfectly straight; secondaries about 12 pairs, mostly alternate, thin, immersed, slightly curved upward, camptodrome, arching well inside the margin, each joining the one next above and sending an outside nerve to one of the teeth; nervilles fairly numerous,

[32] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 78, pl. 43, fig. 6, 1898.
[33] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 298, pl. 70, fig. 3, 1918.

thin, approximately at right angles to the secondaries, irregular but mainly percurrent; finer nervation forming a fine, irregularly quadrangular network, deeply immersed.

This species seems to be quite distinct from any other found in the collections from the Spokane area or from the Pacific coast region. It was evidently a thick, coriaceous leaf, probably an evergreen leaf of the type of *Quercus virginiana* Miller—in fact, it is quite like some of the leaves of this somewhat variable species.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Quercus, cup

Plate XXI, Figure 10

The collections contain a number of acorn cups, but most of them are so crushed that it is impossible to make out any satisfactory characters. The present specimen, however, is very well preserved and shows the arrangement and shape of the scales clearly. This cup appears to belong to the white-oak group, and there is some evidence to show that the acorn was practically immersed, as in the living *Quercus lyrata*, but this is not certain. It was of course the fruit of one of the species characterized from the leaves, but there is no means of connecting them.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Quercus, acorn

Plate XIX, Figures 8, 9; Plate XXI, Figures 8, 9

This is clearly the impression of a small acorn. It is ovoid, with a rather broad, truncated base. The length is about 12 millimeters and the width or diameter about 7 millimeters. There are no pronounced surface markings.

This is presumably the fruit of one of the forms described from the leaves, but as there is no way of connecting them, it is best retained as above.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and submitted by the Spokane Public Museum.

Order URTICALES

Family ULMACEAE

Ulmus speciosa Newberry

Plate XVIII, Figure 6

Ulmus speciosa Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 507, 1883; U. S. Geol. Survey Mon. 26, p. 80, pl. 45, figs. 3, 4, 1898.

The specimen figured is the only one noted in these collections. It is nearly perfect, being about 12 centimeters long and 5.5 centimeters wide. The margin is not as well preserved as could be desired, but so far as can be noted the teeth are large, sharp-pointed, and with only a few secondary teeth. Many of the teeth are without a trace of a smaller tooth, and those present are only very slight projections. The secondaries, of which there are about 15 pairs, are both opposite and alternate, close, parallel, and ending in the teeth. The nervilles are numerous, somewhat irregular but mainly percurrent, and at right angles to the secondaries. The finer nervation forms an irregular fine-meshed, quadrangular areolation.

I do not see how this leaf can be held distinct from the larger of the leaves referred by Newberry to his *Ulmus speciosa*, from Bridge Creek, Oreg. Newberry described his species as doubly serrate, but in the figures he gives only a few of the teeth near the middle of the leaf have additional smaller denticulations, thus agreeing with the Spokane leaf. *Ulmus speciosa* was reported by Penhallow [34] from beds supposed to be of Oligocene age in British Columbia.

This species is of the same type and, indeed, is very closely related to *Ulmus pseudo-fulva* Lesquereux,[35] from the auriferous gravels of California, and also reported from the Miocene of Lamar River, Yellowstone National Park. It is a smaller leaf—8.5 centimeters long and 3.5 centimeters wide—than the leaves now referred to *Ulmus speciosa* and is also described as being doubly serrate, but the secondary teeth are an inconspicuous feature. If a series of specimens from California and Oregon and Washington could be assembled it might well enough be shown that these supposed distinct species should really be merged.

Ulmus tanneri Chaney [36] also belongs to this group—in fact, it is in part based on two of the smaller leaves of *Ulmus speciosa* as figured by Newberry. It is still smaller than *Ulmus pseudo-fulva* Lesquereux but does not greatly differ otherwise.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway west of Latah Creek, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Ulmus fernquisti Knowlton, n. sp.

Plate XIX, Figure 2

Leaf small, about 4.5 centimeters long, 1.5 centimeters wide, evidently coriaceous, lanceolate, slightly unequal-sided at the base, acuminate at the apex; margin coarsely and simply dentate, the teeth deltoid and large for the size of the leaf; petiole about 5 millimeters long; midrib straight, very strong; secondaries about 16 pairs, mostly opposite, close, parallel, little curved upward, each ending in a marginal tooth; finer nervation not retained.

[34] Penhallow, D. P., Report on the Tertiary plants of British Columbia, p. 94, 1908.

[35] Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, No. 2, p. 16, pl. 4, fig. 3, 1878.

[36] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 172, pl. 14, figs. 1, 2, 1920.

This little leaf, the only one noted in the collections, seems to belong to *Ulmus*, but it differs from most of the elms in having the margin simply instead of doubly serrate. All the living American species are doubly serrate, but some of the European forms are simply serrate. It also resembles *Planera* in that the leaves are simply serrate, but the general facies is more that of *Ulmus*.

Several long, narrow leaves representing species of *Ulmus* from this region have been described, but they all differ in being conspicuously doubly serrate. Thus *Ulmus tanneri* Chaney,[37] from the Eagle Creek formation of Oregon, is a small-leaved species but is much larger and broader than the one from Spokane and moreover is doubly serrate. The smaller of the two leaves of *Ulmus californica* Lesquereux[38] as figured by Lesquereux, from the auriferous gravels of California, is very much like the leaf under consideration, being only slightly broader, and furthermore it is described as simply serrate. The other type specimen as figured by Lesquereux is very much larger and broader than the one just mentioned and is of course quite different from the Spokane leaf. Although it would perhaps do no great violence to refer this leaf to *Ulmus californica*, it seems advisable to give it a different name pending the collection of additional material, with the admission that it is very closely related to if not indeed identical with *Ulmus californica*. It is named in honor of C. E. Fernquist, the collector.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Family MORACEAE?

Ficus? washingtonensis Knowlton, n. sp.

Plate XXV; Plate XXVI, Figures 1–3

Leaves large, 9 or 10 centimeters wide, 10 or 12 centimeters long, firm, perhaps coriaceous, broadly ovate or nearly circular, equal-sided at the base, which is rounded and truncate in most specimens but in some very obtusely wedge-shaped, the apex apparently rounded and obtuse; the margin is entire with one specimen showing a pronounced boss on one side; petiole stout, more than 3.5 centimeters long; palmately five-ribbed from the top of the thick petiole, the midrib much the stronger, with about three pairs of camptodrome secondaries in the upper part; second pair of ribs strong, at an angle of about 45°, slightly curved upward, joining the lower pair of secondaries on the midrib, each with several branches on the outside; lower pair of ribs very slender, at a right angle or very low angle with the midrib; nervilles numerous, irregular, forming a large meshed, irregular-sized network.

This form is represented by four specimens, one from the Spokane area and the others from Coeur d'Alene. It seems to be congeneric and may indeed be conspecific with what Lesquereux called *Ficus sordida*,[39] from the auriferous gravels of California, since detected in the Miocene of the Yellowstone National Park. It is very much to be doubted, however, that these leaves were correctly referred to *Ficus*. Lesquereux compared his species to *Ficus grönlandica* Heer,[40] from Greenland, but the resemblance is not very close—in fact, Heer's species resembles certain forms that have been referred to *Populus*.

It has been suggested that these leaves from Spokane and vicinity may be referable to the genus *Menispermites* as established by Lesquereux on leaves from the Dakota sandstone. Of the 20 species of *Menispermites* described 9 are found in the Dakota and the others in several Cretaceous formations except a single species, *M. wilcoxensis* Berry,[41] from the Wilcox formation of Louisiana. The typical Cretaceous species of *Menispermites* are more or less three-lobed or with undulate margins and have the major nervation craspedodrome, ending in the lobes or undulations. This last-mentioned character clearly excludes the leaves under consideration and apparently also *Menispermites wilcoxensis*, in which all the ribs and secondaries are distinctly camptodrome. The Wilcox species may be congeneric with the Spokane leaves. Some of the Cretaceous leaves included in *Menispermites* are more nearly circular and distinctly peltate. These have a camptodrome nervation, thus disagreeing with the type species of the genus. The whole aggregation seems in need of revision.

A careful comparison of the Spokane leaves with *Ficus sordida* discloses some differences. Thus the California species is somewhat larger, and the lateral and basal pairs of ribs have a greater number of secondaries, especially the basal pair, and those are more regular. The finer nervation also differs somewhat.

Although it is probable that those leaves do not belong to *Ficus*, in the absence of any other probable generic designation I am constrained to refer them to *Ficus* but with a distinct mark of interrogation. They are easily recognizable, and when more data are available they can easily be transferred to another genus.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920 (Pl. XXVI, figs. 1–3); Spokane, Wash., collected by C. E. Fernquist May, 1922 (Pl. XXV).

[37] Chaney, R. W., op. cit., p. 172, pl. 14, figs. 1, 2.

[38] Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, p. 15, pl. 4, fig. 2, 1878.

[39] Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, p. 17, pl. 4, figs. 6, 7, 1878.

[40] Heer, Oswald, Flora fossilis arctica, vol. 2, No. 4, pl. 54, fig. 2, 1869.

[41] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 218, pl. 115, figs. 1, 2; pl. 116, figs. 2, 3, 1916.

Order THYMELALES

Family LAURACEAE

Laurus similis Knowlton

Plate XXIII, Figures 4–6; Plate XXIV, Figure 2

Laurus similis Knowlton, U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 48, pl. 5, figs. 1–4, 1900.

Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 173, 1920.

This species was described from specimens collected at Comstock, Douglas County, Oreg., in beds interbedded with lavas on the west side of the Cascade Range and was also noted by Chaney in the Eagle Creek formation at several localities in Multnomah County, Oreg. The two specimens here figured do not appear to differ essentially.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway and Deep Creek half a mile above mouth, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922; cut on Chicago, Milwaukee & St. Paul Railway, Spokane; collected by R. W. Chaney, 1922; specimen in University of California Museum, $\frac{3940}{22859}$.

Laurus princeps Heer

Plate XXIII, Figures 1–3

Laurus princeps Heer. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 250, pl. 58, fig. 2, 1883.

Except for the fact that the Spokane leaves are a little narrower they do not differ from the leaf from the auriferous gravels of Corral Hollow, Alameda County, Calif., figured by Lesquereux. Whether or not the American leaves are identical with European leaves is a matter that need not be discussed here.

Another very perfectly preserved example is still narrower but does not otherwise differ essentially.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922; well at Mica, southeast of Spokane, collected by Thomas Large for J. T. Pardee, August, 1922.

Laurus californica Lesquereux

Laurus californica Lesquereux, U. S. Geol. Survey Terr., vol. 8 (Cretaceous and Tertiary floras), p. 252, pl. 57, fig. 3; pl. 58, figs. 6–8, 1883.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Laurus grandis Lesquereux

Plate XXIV, Figure 1 .

Laurus grandis Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 251, pl. 58, figs 1, 3, 1883.

The specimen here figured appears to approach most closely *Laurus grandis* as figured by Lesquereux. It is not so broad as the larger of Lesquereux's two types but is close to the smaller one. It may be only a very broad leaf of *Laurus princeps* Heer as identified by Lesquereux[42] and as also identified from this collection, but as it is so much larger and has the secondaries fewer and ascending for long distances it seems nearer *L. grandis*.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922; cut 1 mile west of Shelley Lake, 10 miles east of Spokane, collected by Henry Fair, 1922.

Order RANALES

Family MAGNOLIACEAE

Magnolia dayana Cockerell

Plate XXIV, Figure 3

Magnolia dayana Cockerell, Am. Naturalist, vol. 44, p. 35, 1910.

Magnolia lanceolata Lesquereux, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, p. 24, pl. 4, fig. 4, 1878.

The Spokane material includes a single magnolia leaf—the one here figured—that is almost an exact duplicate of the original figure given by Lesquereux of a leaf from the auriferous gravels at Chalk Bluff, Nevada County, Calif. The California leaf was named *Magnolia lanceolata* by Lesquereux, but this name was found to be preoccupied, and it was renamed *M. dayana* by Cockerell. The Spokane leaf is nearly perfect, lacking only the apical portion. It must have been about 17 or 18 centimeters long when perfect and is 6 centimeters wide. The type is about 21 centimeters long and 6 centimeters wide. The nervation of the Spokane leaf agrees perfectly with that of the type, and there can be no doubt of their identity. As Lesquereux pointed out, this species agrees closely, except for its slightly smaller size, with the living *Magnolia acuminata* Linné, the well-known cucumber tree of eastern North America.

Occurrence: Latah formation, Spokane, Wash., collected by T. A. Bonser.

Magnolia sp.

Plate XXVII, Figure 1

In one of the collections procured in 1923 within the city limits of Spokane there are a number of more or less fragmentary large leaves that appear to belong to *Magnolia*. One of the best preserved of these, here figured, lacks the apical portion and most of one side. It appears to have been nearly elliptical, probably at least 15 centimeters in length and about 6 centimeters in width. The petiole is preserved for a length of nearly 2 centimeters, but it was presumably somewhat longer. The midrib is extremely strong. The secondaries are numerous, a dozen pairs or more, thin,

[42] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 250, pl. 58, fig. 3, 1883.

irregular, and at various angles, those near the base being nearly at a right angle, increasing above to an angle of approximately 45°; they are camptodrome, arching just inside the margin. Except for an occasional nerville the finer nervation is not preserved.

This leaf has the appearance of having been thick and coriaceous, in this respect resembling the living *Magnolia foetida* Sargent (*Magnolia grandiflora* of authors), the well-known evergreen magnolia of the Middle Atlantic and Gulf States, with which it also agrees in size and shape, in the thick midrib, and in other features. It is of course presumptuous to assume that this was an evergreen species, perhaps the forerunner of *Magnolia foetida*, but it certainly most resembles that species.

There is another less perfect leaf in the collection that seems to have been more nearly obovate-elliptical and has the secondaries more widely spaced in the upper portion. It is too fragmentary to figure.

Of the several species of *Magnolia* that have been reported from deposits associated with the Columbia River lavas this is most like what has been identified as *Magnolia inglefieldi* Heer,[43] as found in the Mascall formation,[44] but it appears to differ in its more elliptical outline and in the thicker midrib and more numerous secondaries, though a larger series might show less difference.

The specimens available are so fragmentary that it has seemed best not to give a specific name until more and better material is available.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash.. collected by Henry Fair and Kirk Bryan, 1923.

Order ROSALES

Family HAMAMELIDACEAE

Liquidambar pachyphyllum Knowlton

Plate XXII, Figure 7; Plate XXIX, Figure 1

Liquidambar pachyphyllum Knowlton, U. S. Geol. Survey Bull. 204, p. 63, pl. 9, fig. 1, 1902.
Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 174, pl. 15, figs. 2, 3, 1920.

Several more or less fragmentary leaves of *Liquidambar* are included in the Spokane material and are believed to be identical with *Liquidambar pachyphyllum* Knowlton, from the Mascall formation of the John Day Basin, Oreg. The example here figured is a little larger than any heretofore referred to this species, but it does not differ otherwise in essential particulars. The average size before reported is from 6.5 to 7.5 centimeters long and 7 centimeters broad, whereas the specimen here figured must have been nearly 10 centimeters broad and probably about 8 or 9 centimeters long. A thick carbonaceous film represents the thick substance of the leaf in the type specimen as described. Where this substance has crumbled away along the margins of the lobes it has obscured the teeth, but where well preserved the teeth can be seen as in the type.

Liquidambar pachyphyllum was found by Chaney [45] at a number of localities in the Eagle Creek formation of Multnomah County, Oreg. An additional well-preserved specimen was found by Messrs. Fair and Bryan in 1923. This specimen (Pl. XXII, fig. 7) is indistinguishable from the smaller of the two leaves figured by Chaney. In the same beds with this leaf is the finely preserved fruit (Pl. X, fig. 10) that is probably the fruit of this species, though there is no possibility of connecting them organically.

Occurrence: Latah formation, well near Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922; cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, May, 1923.

Liquidambar, fruit

Plate X, Figure 10

This fruit was found in the same beds as the species last discussed and in all reasonable probability belongs to it, but as they are not organically connected they are perhaps best kept separated. This head is very perfectly preserved and shows many of the individual fruits around the outer margin. These are somewhat shorter and not so pointed as in the living species (*Liquidambar styraciflua* Linné).

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash , collected by Henry Fair and Kirk Bryan, May, 1923.

Family SAXIFRAGACEAE

Hydrangea bendirei (Ward) Knowlton

Plate XXIV, Figure 6

Hydrangea bendirei (Ward) Knowlton, in Merriam, California Univ. Dept. Geology Bull., vol. 2, No. 9, p. 309, 1901.
Knowlton, U. S. Geol. Survey Bull. 204, p. 60, pl. 9, figs. 6, 7, 1902.
Marsilea bendirei Ward, U. S. Geol. Survey Fifth Ann. Rept., p. 446, 1885.
Porana bendirei (Ward) Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 16, pl. 8, fig. 4, 1888.

The example figured is the only one thus far observed. It is absolutely indistinguishable from the type specimens and has not before been found except at the type locality.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and donated by the Spokane Public Museum.

[43] Heer, Oswald, Flora fossilis arctica, vol. 1, pl. 15, figs. 4, 5; pl. 18, figs. 1–3, 1868.
[44] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 58, 1902.
[45] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 174, pl. 15, figs. 2, 3, 1920.

Family DRUPACEAE

Prunus rustii Knowlton, n. sp.

Plate XXIV, Figures 4, 5

Leaves small, evidently rather thin and membranaceous, lanceolate or slightly ovate-lanceolate, rounded and obtusely wedge-shaped at the base; apex missing but probably acuminate. The margin is finely and sharply serrate, with a slight tendency for the teeth entered by the secondaries to project beyond the line of the others, the teeth apparently glandular-tipped. The petiole is long and slender, nearly 1.5 centimeters long, and the midrib rather thin and straight. There are probably eight or ten pairs of thin, opposite or subopposite secondaries that stand at an angle of about 45°, regularly spaced and craspedodrome, many of them with three or four short tertiary branches which pass to marginal teeth; nervilles numerous, both broken and percurrent; finer nervation producing a fine, irregularly quadrangular network.

This species is represented by two specimens, both of which are figured. The smaller specimen (fig. 4), from Coeur d'Alene, lacks the apex and most of one side. It was probably about 4.5 centimeters long and 2.25 centimeters wide. The other example (fig. 5), from Spokane, lacks only the apical portion, the remainder being exceptionally well preserved. It was probably 6 centimeters or more in length and is 2.5 centimeters wide. This leaf has the secondaries at a slightly more acute angle than the smaller leaf, but otherwise there is no essential difference.

Among living species *Prunus rustii* suggests *Prunus angustifolia* Marshall, of the Atlantic and Gulf States from Delaware southward, except that there is no evidence of glands at the top of the petiole. Among fossil species from this region it is perhaps closest to *Prunus? tuffacea* Knowlton,[46] from the Mascall formation, but in that species the secondaries are more numerous and at a lower angle of divergence, and not all the secondaries end in marginal teeth.

I take pleasure in naming this species in honor of Mr. H. J. Rust, who collected one of the types.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920; cut No. 2 on Chicago, Milwaukee & St. Paul Railway, Wash., collected by Henry Fair and Kirk Bryan, 1923.

Family CAESALPINIACEAE

Cercis? spokanensis Knowlton, n. sp.

Plate XXIX, Figure 9

Pod linear or linear-oblong, flat, with a short stalk, the valves apparently thin, thickened along the upper suture, reticulate-veined, apparently with several seeds.

[46] Knowlton, F. H., U. S. Geol. Survey Bull. 204, pl. 11, figs. 2, 3, 6, 7, 1902.

This little pod is now about 3.5 centimeters long (including the stalk, which is 4 millimeters in length) and 1.5 centimeters wide. The valve, as may be seen from the drawing, is finely reticulate-nerved, and there is a faint indication of the presence of three large round seeds.

Although the apparent affinity of this species is with the living *Cercis canadensis* Linné, it has seemed best to question the generic reference, for the identification is more or less uncertain.

Occurrence: Latah formation, Deep Creek half a mile above mouth, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Family PAPILIONACEAE

Sophora alexanderi Knowlton, n. sp.

Plate XXVIII, Figures 3–5

Leaflets thin, elliptical or slightly ovate-elliptical, 2.5 to 3.25 centimeters long, 12 to 16 millimeters wide, broadest near or just below the middle, abruptly rounded or even slightly heart-shaped at the base, obtuse, with a distinct tendency to be slightly emarginate, at the apex; margins entire; petiole short, stout; midrib relatively very strong; secondaries about eight or nine pairs, at somewhat irregular distances, considerably curved upward, strongly camptodrome, arching well below the margin and each passing to the secondary next above; finer nervation producing a rather large, irregularly quadrangular network.

There is considerable variation in the size and shape of the three examples referred to this species, but as they come from the same locality and have certain characters in common it is assumed that they are only variants of a single species. Thus, the leaf shown in Figure 4 is relatively long, truncate at the base, and minutely emarginate at the apex. That shown in Figure 5 is slightly heart-shaped at the base and also minutely emarginate. The one shown in Figures 3 and 3a is shorter, relatively broader, rounded at the base, and distinctly emarginate at the apex. The thick midrib and irregularly spaced camptodrome secondaries are the same in all.

Little leaves or leaflets of this type are difficult to place satisfactorily, yet these appear to agree well with others that have been referred to *Sophora*. For example, the present species is very similar to *Sophora wilcoxiana* Berry,[4] from beds of Wilcox age in the Lagrange formation of Tennessee, though there are minor differences in the nervation.

I take pleasure in naming this little species in honor of Mr. A. C. Alexander, of Spokane, who has done much to develop the mineral resources of the region and who has been especially interested in finding and collecting fossil plants.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

[4] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 241, pl. 47, figs. 1–13, 1916.

Sophora spokanensis Knowlton, n. sp.

Plate XXVIII, Figure 6

To found a species on this little fragment is perhaps unwise, but it appears to differ from anything else from these beds and can probably be recognized if again found. It is elliptical-lanceolate, with a rounded and obtuse apex and probably a somewhat similarly rounded base. The length was probably not far from 4 centimeters and the width a little over 1 centimeter. The nervation consists of a relatively very thick midrib and numerous alternate thin camptodrome secondaries at a low angle of emergence. The finer nervation can not be made out with certainty.

This little leaflet is the only one found. It differs from the preceding species, *Sophora alexanderi*, in being relatively longer and narrower and in the more numerous, lower-angled secondaries. It is very similar to certain of the intermediate-sized leaflets of *Sophora wilcoxiana* Berry,[48] from beds of Wilcox age in the Lagrange formation of Tennessee—in fact, it is difficult to note characters for their separation.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 3, 1923.

Robinia? sp.

Plate XXVIII, Figures 7, 7a

Leaflet thin, elliptical-ovate, 15 millimeters long, 9 millimeters wide, rounded and truncate or almost heart-shaped at the base, obtuse at the apex; petiolule very short, slightly over 1 millimeter; nervation light, consisting of a straight midrib and about seven pairs of thin camptodrome secondaries at an angle of about 50°; finer nervation not discernible.

Isolated leaflets of this character are so small and generally nondescript that it is almost impossible to place them satisfactorily. The most that can be said in the present instance is that it resembles the leaflets of certain living species of *Robinia*, such for example as *R. pseudacacia* Linné, of eastern North America, but it is difficult to establish identity. It will at least call attention to the presence of this type of plant, but the future will have to settle its identity.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Genus MEIBOMITES Knowlton, n. gen.

Characters of the species.

Meibomites lucens Knowlton, n. sp.

Plate XXVIII, Figure 10

This appears to be of the type of the lateral leaflet in many living species of *Meibomia*. It was clearly thin. It is very broadly ovate, being abruptly rounded below to the nearly truncate base and above to a slender acute tip. The margin is perfectly entire, and the petiolule if ever present is not now preserved. The nervation is very thin and delicate, consisting of a slender, straight midrib and eight or nine pairs of camptodrome secondaries. The lowest pair arise at the extreme base of the blade at an angle of approximately 45°; the others are at irregular distances and at an angle of 30° or 40°; all are curved upward, and each joins the one next above, far inside the margin. Between these loops and the margin is a series of large and small loops. The nervilles are not very numerous and are very thin, mainly percurrent. The finer nervation produces very irregular areas.

The genus *Meibomia* comprises about 160 species, natives of warm and temperate North and South America, South Africa, and Australia. They are perennial herbs, often woody at the base, mainly with trifoliolate leaves. The terminal leaflet is short-petioled, but the lateral ones are almost always closely sessile. The fruit consists of a flat loment of several coriaceous jointed indehiscent segments. No part of the plant has apparently been found in a fossil state.

The present specimen appears to me to be a sessile lateral leaflet very similar at least to those of a number of living species, such as *Meibomia arenicola* Vail and *M. ochroleuca* (Curtis) Kuntze, but as those species seem to have a more regularly pinnate nervation it seems best not to refer the Spokane form to the living genus direct, hence I have erected the new genus *Meibomites* for it.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Order SAPINDALES

Family CELASTRACEAE

Celastrus fernquisti Knowlton, n. sp.

Plate XXVIII, Figure 2

Leaf evidently thin, elliptical or elliptical-ovate, about 7 centimeters long and 5 centimeters wide, broadest about the middle, rather abruptly rounded to the truncate, slightly heart-shaped base and apparently to a moderately pointed apex; margin entire at base, thence serrate, the teeth somewhat irregular, sharp; midrib strong, particularly below; secondaries about seven pairs, subopposite, all but the lowest pair at an angle of about 40°, slightly curved upward, craspedodrome, those in the middle of the blade with several tertiary branches which also terminate in the teeth; nervilles numerous, thin, often broken.

This species is represented by the half of a leaf as figured, which shows the base very well but lacks the extreme tip. The petiole is not retained. The marginal teeth and the nervation are well shown in the figure.

[48] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 241, pl. 47, figs. 1–13, 1916.

This species seems undoubtedly congeneric with a number of species from the Fort Union formation described by Ward [49] as *Celastrus*. These forms were abundant in the Fort Union formation, and one of the species (*C. taurinensis*) was recognized by Berry [50] in the Wilcox formation of Louisiana. The leaf under consideration agrees very well with some of the Fort Union forms, especially *C. taurinensis*, but differs in having fewer secondaries, which are not so much curved upward.

In his original discussion of *C. taurinensis* Ward debated whether or not it might better be referred to *Grewiopsis* or *Pterospermites*, and Berry states that if it had to be described anew he would be inclined to place it in *Grewiopsis*, but, be this as it may, the present form seems near enough to be considered congeneric with it, and thus it is left until a revision and full consideration of the Fort Union flora is made.

I take pleasure in naming this species in honor of Mr. C. E. Fernquist, of Spokane, who collected it.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway west of Latah Creek, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Family ANACARDIACEAE

Rhus typhinoides Lesquereux

Plate XXVII, Figure 5

Rhus typhinoides Lesquereux, Harvard Univ. Mus. Comp Zoology Mem., vol. 6, No. 2, p. 29, pl. 9, figs. 1–6, 1878.

The single specimen figured appears to belong to this species. It lacks the upper half, but in size, inequilateral base, marginal teeth, and nervation it agrees well with Lesquereux's figures, except that the secondaries are not so numerous in the basal portion.

Occurrence: Latah formation, north side of clay pit 2 miles south of Vera, Wash., collected by Henry Fair, June 29, 1923.

Family STAPHYLEACEAE

Acer bendirei Lesquereux

Plate XXVII, Figure 3

Acer bendirei Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 14, pl. 5, fig. 5, 1888.

Although the specimen here figured is rather fragmentary, enough of it is retained to show clearly that it is indistinguishable from the leaf figured by Lesquereux, as noted above. In the same paper Lesquereux figured several other much larger leaves, and in a still earlier paper [51] specimens even larger were figured under the name *Acer trilobatum productum* Heer. They are all from the Mascall formation of the John Day Basin, Oreg.

It has been suggested that these leaves figured by Lesquereux, especially the larger ones, are more properly referable to *Platanus* than to *Acer*. Be that as it may, the present leaf certainly agrees with the specimen quoted above.

Occurrence: Latah formation, well at Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922.

Acer merriami Knowlton

Plate XXVIII, Figure 1

Acer merriami Knowlton, U. S. Geol. Survey Bull. 204, p. 74, pl. 14, fig. 7, 1902.

Hardly more than the basal portion of this leaf, with the petiole complete, is preserved, but as it agrees with the type leaf of *Acer merriami*, it is so identified.

Occurrence: Latah formation, well at Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922.

Acer minor Knowlton

Plate XXVII, Figure 4

Acer minor Knowlton, U. S. Geol. Survey Bull. 204, p. 76, pl. 14, figs. 2, 3, 1902.

Although it may be more or less hazardous to identify species of maple from fruits, the present identification seems fairly certain. Three species based largely on size of fruits were characterized from the Mascall formation of the John Day Basin, and as no intermediate sizes were noted it was assumed that the species were valid, each perhaps corresponding to one of the three species characterized from the leaves.

Maples do not seem to have been as abundant in the Spokane area as they were in the John Day Basin, the fruit figured being the only one that has come to my attention.

This species is similar to *Acer aquilum* Chaney,[52] from the Eagle Creek formation of the Columbia River region, but is considerably narrower.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 24, 1923.

Acer chaneyi Knowlton, n. sp.

Plate XXVII, Figure 2

Leaf rather thin, rudely triangular, truncate at the base, very deeply three-lobed, the basal lobes lanceolate, sharp-pointed, with a small basal lobe and in the middle a larger few-toothed lobe on either side, the upper part sharply toothed; middle lobe with a pair of opposite toothed lobes high above the sinus and probably a toothed margin still above this (apex destroyed); sinuses very deep, rather sharp; nervation

[49] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., p. 555, pl. 52, 1886; U. S. Geol. Survey Bull. 37, p. 79, 1887.

[50] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 267, pl. 60, figs. 1–3, 1916.

[51] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 253, pl. 59, figs. 1, 2, 4, 1883.

[52] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 178, pl. 18, fig. 2, 1920.

relatively strong, three-ribbed from the very base of the blade; midrib with a slender nerve passing up to and forking around the sinus, with about three pairs of camptodrome secondaries below the first pair of lobes, then a strong pair that end in the apex of the lobes, and above these probably other camptodrome secondaries; lateral ribs nearly as strong as the midrib, at an angle of about 45°, with both camptodrome and craspedodrome secondaries; nervilles slender, forming an irregular network.

This very characteristic species is represented by the single example here figured, which is nearly perfect except for the upper portion of the middle lobe. The length was probably 8 or 9 centimeters and the width between the lateral lobes about 8 centimeters. The lateral lobes are about 5 centimeters long and 1 centimeter wide at the base. The width of the middle lobe just above the sinuses is slightly less than 1 centimeter. The petiole is not preserved.

This species does not appear to approach very closely any living American species, nor is it like any fossil species thus far described from the region. It is, however, similar in many respects to *Acer angustilobum*,[53] from the Swiss Miocene. This European species is of about the same size as ours and is three-lobed and cut deeply by the sinuses, but it differs in having all the lobes evenly and sharply toothed.

I take pleasure in naming this species in honor of Dr. Ralph W. Chaney, who collected it.

Occurrence: Latah formation, Spokane, Wash., collected by R. W. Chaney, July, 1921. Type in the University of California, No. $\frac{3940}{22862}$.

Order ERICALES

Family VACCINIACEAE

Vaccinium salicoides Knowlton, n. sp.

Plate XXVIII, Figures 9, 9a

Leaf small (about 2 centimeters long, 6 millimeters wide), very thick, linear-lanceolate, broadest at about the middle, wedge-shaped at the base and rather obtuse at the apex; margin perfectly entire; midrib very thick, especially where it passes into the petiole; secondaries five or six pairs, thin, curving upward for long distances, camptodrome, each joining the one next above by several loops; finer nervation producing a regular, deeply impressed quadrangular network.

With only a single small rather nondescript leaf for comparison it is difficult to place this form with certainty. It is not unlike leaves of the living *Vaccinium pennsylvanicum* Lamarck, though apparently somewhat thicker. It also resembles certain species of *Salix* but is thicker than is usual in willow leaves.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

[53] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, pl. 118, fig. 7, 1859.

Order EBENALES

Family EBENACEAE

Diospyros andersonae Knowlton, n. sp.

Plate XXVII, Figure 6

This species, based on the splendid calyx figured, is so close to the living persimmon (*Diospyros virginiana* Linné) that separation is hardly possible, but it is so far outside the present range of this living species that its persistence since the Miocene seems improbable. The fossil form, however, is somewhat smaller than the usual-sized calyx in *Diospyros virginiana* and has the lobes relatively broader and shorter, but at most the differences are not great. It has a spread over all of 3 centimeters, and the greatest width of the lobes is 11 or 12 millimeters. The length of the lobes is about the same as their width. This calyx is preserved right side up, so to speak, and was evidently mature when fossilized, for the central depression or "cup" in which the berry rested is pronounced. In the living species the berry adheres to the calyx with great tenacity until maturity, when it readily separates.

Diospyros virginiana, the well-known persimmon, is very common in the South Atlantic and Gulf States, ranging from Connecticut west to Iowa and thence south through eastern Kansas to Arkansas and Louisiana. It is not known west of the Mississippi basin. It is evident that the type almost in its present form was in existence in middle Miocene time and at least a thousand miles west of its present western limit.

The Spokane persimmon is named in honor of Miss Alice Anderson, who collected it.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Alice Anderson for the Spokane Museum, from which the specimen is contributed.

Diospyros? microcalyx Knowlton, n. sp.

Plate XXII, Figures 5, 6

This species is represented by the two examples figured. They clearly represent a dry, leathery calyx from which the berry or fruit of some kind has fallen. They are regularly five-lobed, the individual lobes being obovate or oblong and very obtuse and rounded at the apex and cut within a short distance of the central disk. The nervation of the lobes is obscure but apparently consists of fine veins that run through the whole length. The central disk or point of attachment for the berry is over 1 millimeter in diameter and shows faint outlines of five vascular bundles. The width between the tips of the lobes is 8 or 9 millimeters.

I am less certain about the correctness of this generic reference than for the species last described, but it seems to approach most closely the calyx of the black persimmon (*Diospyros texana* Scheele, *Brayodendron texanum* (Scheele) Small) of Texas and Nuevo Leon, Mexico. It is, however, very much smaller and has the lobes relatively broader and more obtuse than in this living species.

These Spokane specimens also resemble certain species of *Porana* from the lake beds at Florissant, Colo., such as *Porana cockerelli* Knowlton,[54] although the latter is many times larger and has the ovoid capsule preserved in the center. The lobes of the calyx in *Porana cockerelli* have only about three strong nerves running from the base to the apex, whereas in the specimens under consideration there are a great number of fine veins or wrinkles that simulate veins. Another species of *Porana* (*P. similis* Knowlton), also from Florissant, is similar to *P. cockerelli* but has the calyx lobes pointed instead of obtuse. This also has the capsule preserved.

Altogether the Spokane specimens seem more like *Diospyros* than *Porana*, but considering the uncertainty it has appeared best to question the generic reference.

Occurrence: Latah formation, deep cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and contributed by the Spokane Public Museum.

Order MALVALES

Family MALVACEAE

Malva? hesperia Knowlton, n. sp.

Plate XXIX, Figure 11

Fruit depressed globose, about 1 centimeter in diameter, made up of a ring of about 20 indehiscent, smooth carpels that are without apparent beak or reticulations.

The specimen figured, the only one observed, is fortunately preserved in a normal position, so that all the carpels are exposed. It is certainly malvaceous and seems to be generically identical with the fruits of species of *Malva*, such as *Malva alcea* Linné and *M. moschata* Linné, but *Malva* is not a native of North America. The genus comprises about 30 Old World species, five or six of which are more or less widely naturalized in this country. It is also like *Althea*, but this is an Old World genus of some 15 species, only one of which (*A. officinalis* Linné) has been introduced into North America.

There are a number of native genera with the fruit more or less like the Spokane specimen, such as *Callirrhoë*, but the carpels of *Callirrhoë* are beaked and are also more or less reticulated. Others, such as *Malvastrum* and *Sida*, are eliminated for similar reasons.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and submitted by the Spokane Public Museum.

[54] Knowlton, F. H., U. S. Nat. Mus. Proc., vol. 51, p. 287, pl. 27, fig. 3, 1917.

PLANTS OF UNCERTAIN SYSTEMATIC POSITION

Phyllites amplexicaulis Knowlton, n. sp.

Plate XXIX, Figure 3

This is a very peculiar organism, the exact nature of which has not yet been interpreted. It consists of a stout stem, of which 7.5 centimeters in length is preserved, on which are at irregular intervals (2 to 3 centimeters) pairs of small opposite, sessile, flat expanded organs. These are approximately circular, from 7 to 10 millimeters in width or diameter, and with the margin cut into regular strong deltoid teeth. From the center or point of attachment there are some eight or nine strong, straight ribs, which enter the teeth. No finer nervation can be detected. These organs seem to be coriaceous and to be stipular rather than strictly foliar in function. At the points of attachment the stem is constricted or disorganized, as if there had been other organs that have now disappeared.

I am not able to suggest any affinity for this organism.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Phyllites crustacea Knowlton, n. sp.

Plate XXIX, Figure 6

This little leaf, the only one of its kind observed in the collection, is narrowly lanceolate, broadest well above the middle, whence it narrows below to a long wedge-shaped base and above to the acutely pointed tip. It is about 5 centimeters long and 1 centimeter wide. It was evidently rather thick, for over most of the leaf the carbonaceous film still remains. This carbonaceous matter has checked and wrinkled in such a manner that the nervation is obscured, and where it has been removed the impression of the nervation is hardly discernible. If correctly interpreted there appear to have been a large number of light, close, parallel secondaries that are apparently craspedodrome. The midrib seems strong for the size of the leaf. None of the finer nervation can be made out.

This little leaf has some resemblance, in shape at least, to certain narrow, entire-leaved species of *Salix*, but the nervation is so uncertain that it is best placed in *Phyllites*. It also agrees in shape with the smaller of the figured types of *Laurus salicifolia* Lesquereux [55] (now *L. saliciformis* Knowlton and Cockerell), but it has more secondaries and no evidence of the very fine nervation of that species.

Occurrence: Latah formation, well at Mica, southeast of Spokane, Wash., collected by Thomas Large or J. T. Pardee, August, 1922.

[55] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 252, pl. 58, fig. 3, 1883.

Phyllites pardeei Knowlton, n. sp.

Plate XXIX, Figure 13

Leaf apparently very thick, elliptical, abruptly rounded to the obtuse base and apex; margin with about four very low, obtuse teeth or lobes on each side; petiole moderately strong, about 1 centimeter long; midrib very strong for the size of the leaf, slightly irregular or bent; secondaries three pairs, all strong and more or less zigzag, the lower pair strongest, subopposite, arising a considerable distance above the top of the petiole, ending in a marginal tooth, each with a series of large loops on the lower side; middle pair of secondaries subopposite, forking and sending the branches to the marginal teeth; upper secondaries alternate, ending in the upper of the four marginal teeth; nervilles few, strong; finer nervation very strong and well marked, producing a network of large, irregular meshes throughout the blade.

This leaf is well characterized by its elliptical shape, the four low, obtuse teeth or lobes on each side, the three pairs of craspedodrome secondaries, the lowest of which are so far above the base of the blade, and above all by the peculiar large-meshed network of finer veins. Nevertheless, I am not now able to suggest a satisfactory generic reference. The shape and the manner in which the lower pair of secondaries arise, as well as the finer nervation, suggest the genus *Oreodaphne*, but the presence of the low marginal teeth or lobes is not in accord with this genus. I am therefore constrained to place it in *Phyllites* until it can be more satisfactorily allocated.

This species has been named in honor of Mr. J. T. Pardee, of the United States Geological Survey, who was especially instrumental in procuring the collections that are the basis of this report.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

Phyllites peculiaris Knowlton, n. sp.

Plate XXIX, Figure 2

Leaf evidently very thick, as the nervation is all deeply impressed; presumably elliptical, though the upper portion is missing; margin apparently entire; midrib extremely strong for the size of the leaf and slightly irregular. The number of pairs of secondaries can not be determined, though there are at least four pairs. The lower pair is rather thin and passes upward for only a short distance; they arise from the top of the petiole. The other secondaries are alternate, at an angle of about 20°, camptodrome, and curving upward for long distances, each joining the one above by a series of loops. There are a number of strong intermediate secondaries and an occasional nerville, but most of the finer nervation is obsolete.

This leaf has some resemblance to *Phyllites pardeei*, but that form has three or four low marginal teeth or lobes, and the lower secondaries arise at a distance above the top of the petiole. This leaf also resembles in a general way certain leaves that have been referred to *Ficus*, but in the absence of more complete data I think best to refer it to *Phyllites*. It can be easily recognized if again found.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

Phyllites sophoroides Knowlton, n. sp.

Plate XXVI, Figure 8

This little leaf or leaflet, as it probably is, is the only one of its kind observed. It was apparently thin and is long elliptical, being about equally rounded at both ends. The base appears to be slightly unequal-sided, and the apex is abruptly apiculate. The midrib is fairly strong, and the secondaries are very thin and delicate. There are nine or ten pairs of rather remote secondaries that curve near the margin, and each passes in a series of bows to the one next above. The nervilles are numerous, very irregular, and with the finer nervation producing a very irregular delicate network. The specimen is 4.75 centimeters long and 2.5 centimeters wide near the middle.

This appears to be a leaflet of a leguminous plant, being, for instance, similar to many that have been referred to *Sophora*, but as there is only a single example, and this not quite perfect, it is best referred, at least, temporarily, to the noncommital genus *Phyllites*.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Phyllites relatus Knowlton, n. sp.

Plate XXVIII, Figure 8

Leaf small, probably about 5 centimeters in length and 2 centimeters in width, ovate-lanceolate; the shape of the base is not known, but the apex is drawn out into a long, slender point; the margin is provided with numerous rather large, slender, sharp-pointed teeth; the midrib is very strong, even to the tip of the blade; the number of secondaries can not be made out, as the basal portion of the leaf is missing, but there must have been nine or ten pairs; they are alternate, mainly irregular or zigzag, slightly curved upward, craspedodrome, often forked, with each branch entering a tooth; nervilles numerous and strong, approximately at right angles to the secondaries, both broken and percurrent; finer nervation producing an irregular network.

I am uncertain as to the generic reference for this little leaf. It is well marked by its thick substance and strong nervation, and particularly by its strong slender teeth, which extend even to the slender acuminate apex. In some ways it suggests *Ilex*, but this resemblance is probably only accidental and not a mark of affinity. It seems best under the circumstances to place the leaf in *Phyllites* for the present, or until better material can be procured.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Phyllites sp.

Plate XXIX, Figure 5

This little leaf is the only one observed. It is apparently rather thick, possibly fleshy, and elliptical, with a rounded, almost truncate base and obtusely acuminate apex; length about 13 millimeters and width about 7 millimeters; petiole only about 1 millimeter long as preserved and very broad and thick; nervation somewhat obscure, but there are five very thin veins or ribs that arise in the petiole and then pass up into the leaf, one of them becoming the midrib and the others becoming vague near the middle of the blade; there is some evidence that several similarly thin veins arise from the middle and upper part of the midrib, but it is not conclusive. The finer nervation is not distinctly preserved.

The affinity of this little leaf is hard to determine. In size and shape it is very much like the floating leaves of some small-leaved species of *Potamogeton*, such as *Potamogeton diversifolius* Rafinesque and *P. spirillus* Tuckerman, but the nervation is not quite so regular.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, May, 1923.

Carpites menthoides Knowlton, n. sp.

Plate XXVI, Figure 4

This is a very peculiar fruit that is difficult to interpret. It is apparently a globular head approximately 2 centimeters in diameter, with an axis that is small below or toward the point of attachment and much swollen above. From all parts of this axis radiate narrow, finer, possibly coriaceous bracts, or something of the kind, that are now concave or possibly they were tubular like the calcyces of the heads of certain menthaceous plants such as *Monarda*. These organs seem to be too firm for the flowers of a composite, though that may be their relationship.

Occurrence: Latah formation, Spokane, Wash., collected by R. W. Chaney, 1921. University of California Museum No. $\frac{3940}{22855}$.

Carpites boraginoides Knowlton, n. sp.

Plate XXIX, Figure 7

This little specimen, although seemingly well preserved, is difficult to interpret, because it can not be viewed on all sides. It consists of a stout pedicel or peduncle about 18 millimeters in length, somewhat enlarged at the top, with what appear to be deflected portions of calyx lobes. On this receptacle are oblong, hard-shelled, perhaps berry-like seeds or nutlets. These are about 5 millimeters long and 4 millimeters broad. There is a hard outer rim or shell, now carbonaceous, and a light-colored inner area that shows faint lines and markings. There is some indication of a columella or axis between the seeds, but this is obscure.

The number of these seeds, nutlets, or whatever they are can not be made out with certainty. If it is assumed that there are four, which seems reasonable, it would suggest certain Boraginaceae in which there are usually four 1-seeded nutlets, but if there were a greater number it might be closer to the Malvaceae. The essential characters that remain in doubt make further speculation hazardous.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

Carpites polygonoides Knowlton, n. sp.

Plate XXVI, Figure 7

As may be seen from the figure, this species is based on a cluster of some 50 or more detached fruits that presumably all came from the same plant. They are flat, circular "seeds" 2 or 3 millimeters in diameter, some of them with a slight point on one side. There seems to be a nucleus in the center, and thus the "seed" seems to be winged. The margin is entire. There are no pronounced or interpretable markings or ribs on the surface.

These fruits suggest the fruits of certain of the larger-seeded species of *Rumex*. Their uniform size, with a central nucleus and apparent winged margin, and above all the close grouping of so large a number are what might be expected of the clustered ripe fruits of *Rumex*, such as *Rumex venosus* Pursh, *R. patentia* Linné, and *R. occidentalis* Watson.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

Carpites spokanensis Knowlton, n. sp.

Plate XXVI, Figure 6

This organism is difficult to describe, because its nature and affinity are not recognized. It is slightly obovoid, about 12 millimeters long and about 6 millimeters broad, and attached by a base that is nearly 5 millimeters broad. At the base there is no apparent differentiation between integument and what seems to be a large ovoid, pointed "seed." From a point about 2 millimeters above the base the differentiation is complete from what appears to be a thick outer envelope. The central body or "seed" is irregularly longitudinally striate.

There is another example by the side of the one just described that is so folded as to give the impression that the outer envelope was two-valved and split apart, exposing the "seed." This may not be the correct interpretation, but it is given for what it is worth.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 10, 1923.

Carpites ginkgoides Knowlton, n. sp.

Plate XXIX, Figure 4

This specimen is clearly a spherical, hard-shelled seed standing on a short, fleshy axis, which is cup-shaped at the top, where stands the seed. The seed is about 11 millimeters in diameter and was undoubtedly spherical, though now one side is crushed down. The shell is about 0.05 millimeter thick and perfectly black. There is no evidence of the presence of an outer flesh, though this might well enough have been present. The seed is now filled with the clay of the matrix and is without further differentiation.

This seed certainly strongly suggests the fruit of the living *Ginkgo biloba* Linné, although it is smaller than the usual-sized fruits of this species. As leaves of *Ginkgo* have been found in these beds there is warrant for this being the fruit, though there is no absolute proof, and hence it seems best to place this form in *Carpites* pending fuller information.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 10, 1923.

Carpites magnifica Knowlton, n. sp.

Plate XXIX, Figure 10

This specimen is difficult to interpret, although seemingly well preserved. It is ovate or ovoid, slightly over 4 centimeters in length and 2.3 centimeters in width. It is abruptly rounded below to the short, stout point of attachment, within which there are three grooves that become ridges a short distance above the base and can be traced upward for two-thirds the length of the specimen. A thin carbonaceous layer 1 millimeter or more thick surrounds the whole specimen and possibly represents a fleshy substance. There are a few irregular ribs or corrugations over the body of the specimen, but otherwise the surface is smooth and unmarked.

This form suggests superficially the nut of a butternut (*Juglans cinerea* Linné), but the resemblance is doubtless fancied rather than real. Its affinity is not known.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Don Engdahl for the Spokane Public Museum.

Carpites paulownia Knowlton, n. sp.

Plate XXIX, Figure 12

This is apparently a woody capsule, splitting into two equal valves. It is oblong or slightly obovoid, about 3.3 centimeters in length and 1.7 centimeters in diameter. It stands on a stout, woody axis, which is enlarged or saucer-shaped at the apex. The axis or branch, as well as the enlarged expansion in which the capsule sits, is deeply impressed and is now changed to a coaly mass.

The resemblance of this specimen to the mature fruit of the living *Paulownia* is striking. In the living species the calyx is trumpet-shaped and deeply 5-cleft, with short, moderately acute lobes; it is leathery in texture when mature. The capsule is coriaceous, ovoid, acute, and loculicidally dehiscent; it is about 5 centimeters long and 2.5 centimeters in diameter. *Paulownia* is a monotypic Japanese genus. It is a large tree with broad leaves 15 to 40 centimeters long and 10 to 20 centimeters wide. It is frequently cultivated in the Eastern States and has now escaped from cultivation in many places from New York and New Jersey southward.

Only a single fossil species of *Paulownia* has been described—*P. europaea* Laurent,[56] from the Pliocene of Cantal, France, based on a leaf that is almost identical with the living *P. tomentosa* (Willdenow) Baillion. The genus has not been detected as fossil in North America. It is possible but not certain that at least one of the leaves described in this paper under the name *Ficus? washingtonensis* (Pl. XXV) may be a leaf of *Paulownia*.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and contributed by the Spokane Public Museum.

Branchlet and bud?

This specimen is obscure but is apparently a large bud. It is borne on a rather slender stem a little over 1 centimeter in length and about 2 millimeters in diameter. It is slightly enlarged at the base of the "bud," which appears to have relatively large, strongly striated scales about 12 millimeters long and 5 or 6 millimeters broad. It does not appear to be a capsule, though it may be. In any event its affinity is unrecognized.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair, June, 1923.

[56] Laurent, L., Faculté sci. Marseille Annales, vol. 14, p. 4, text fig. 1, 1904.

THE FOSSIL DIATOM DEPOSIT AT SPOKANE

By Albert Mann

The shale from Mica, near Spokane, Wash., a sample of which was submitted to me, proves to be moderately rich in fossil diatoms and to differ in several respects from any other diatom deposit located in that part of the world. There are several diatom beds in the Northwest, some covering large areas. All are of fresh-water origin, thus contrasting with the beds in California and Mexico, which are uniformly marine. But although the Spokane strata, like the others, were laid down in inland lakes, the formation has otherwise little similarity.

It is not unusual for contiguous diatom formations to show dissimilarity in their flora. The subfossil deposit of the Klamath Lake district of southern Oregon is characteristically local, but neither it nor any of the other deposits is as distinctive as this one at Spokane. For example, the fossil diatoms of the Northwest are largely made up of one species, a minute but robust filament-forming diatom, *Melosira granulata* (Ehrenberg) Ralfs, and in some beds it composes practically the entire mass. In fact, it may be said to characterize the diatom earths of that part of the world. But in the Spokane material this species is so rare that it is practically negligible; on the other hand, the Spokane flora comprises a number of species that are strikingly odd and some that have never been found before in this country.

This singularity of the Spokane deposit is apparent also in the greatly modified condition of the entire diatom mass. Most of the specimens are badly decayed or "rotten," a condition usually met with wherever a deposit has been subjected to long periods of alkaline corrosion. But in this area the caustic action of the water appears to have been somewhat operative during the time when the diatoms were living and the strata were being laid down, as well as during some long subsequent period. For not only are the specimens as a whole corroded, but many of them were originally misshapen in form and blurred in their ornamentation, indicating that their growth took place under unfavorable influences. Such an assemblage of crippled and malformed individuals is known to be the result of a high percentage of mineral salts in the water during the period of diatom growth, and several papers on this condition and its effect have been published.

But there is a curious and quite exceptional phase of this growth of malformations observable in the Spokane material, namely, a tendency in several of the species to develop twin specimens—that is to say, two complete diatoms, inseparably grown together. That such twins represent a real growth product and not the subsequent gluing together of two adjacent diatoms nor their partial fusion by means of geologic heat is easily seen. An examination of the illustrations of such twins which accompany this report and still more a microscopic study of the specimens themselves will make this fact evident. I think it is safe to infer that these twin diatoms were caused by some effect of certain mineral constitutents of the water acting on the diatoms during the plastic period of their vegetative reproduction—that is to say, during that well-known process by which each individual diatom becomes two individuals by the formation of two new valves developed back to back within the two older valves of each parent plant.

From the foregoing facts it is permissible to conclude that the Spokane diatom deposit was formed in a comparatively shallow inland lake, nominally a fresh-water lake but holding in solution a considerable amount of mineral constituents, probably derived from surface drainage and gradually increased by the absence of any adequate outlet; furthermore, that these conditions continued not only during the period of diatom growth, as is indicated by the malformations of the individuals, but also after the deposit had been laid down, as is shown by the corrosion and rottenness of a great part of the diatom mass.

The following is a list of the genera and species of diatoms found in the Spokane material. It is practically complete, so far as the sample examined is concerned; but this does not imply that other species might not be found in samples taken some distance from the location of this one, or from other strata above or below this one at the same locality. Diatomists are familiar with the fact that two samples taken at different places in the same bay at the present time may show considerable variation in the species they contain; and samples taken at exactly the same spot after a lapse of several years are even more likely to be dissimilar. Of course the same tendency to variation existed in those remote periods of time when the diatom beds now represented by fossils were being laid down. It is therefore obvious that a list of species found in a single fossil sample of diatoms is presumably somewhat fragmentary.

The list contains references to the particular illustrations in well-known works which most accurately represent the specimens found in the Spokane deposit. The following abbreviations are used:

Cl. Nav. Diat.—Cleve, P. T., Synopsis of the naviculoid diatoms, 1894–1895.

Donk. Brit. Diat.—Donkin, A. S., The natural history of the British Diatomaceae, 3 pts., 1871–1872.

Ratt. Rev. Cosc.—Rattray, John, A revision of the genus *Coscinodiscus*, 1889.

Reise F. Nov.—Grunow, Albert, Reise der Fregatte *Novara*, 1857–1859, Bot. Theil, Band 1, Heft 1, 1870.

Sch. At.—Schmidt, A., Atlas der Diatomaceen-Kunde, 1874–1921.

S. B. D.—Smith, William, A synopsis of the British Diatomaceae, 2 vols., 1853, 1856.

V. H. Syn.—Van Heurck, Henri, Synopsis des diatomées de Belgique, 1880–1885.

References to illustrations are given in the form 26/29–30—that is, Plate 26, figures 29–30.

Achnanthes (Achnanthidium) flexella (Brebisson). V. H. Syn., 26/29–30.

Actinella brasiliensis Grunow. V. H. Syn., 35/19.

Amphipleura pellucida var. *oregonica* Grunow. Cl. Nav. Diat., vol. 1, p. 126; V. H. Syn., 17/14–15.

Coscinodiscus subaulacodiscoidalis Rattray. (See Pl. XXX, fig. 1.) This ordinarily very rare diatom is rather abundant in the Spokane material. It seems to have never been found before in this country. Its type is figured in Sch. At., 57/8 without name and is named in Ratt. Rev. Cosc., p. 521; the specimen was found at Baldjik, on the Black Sea. My specimens have only three or four processes.

Cymbella americana Schmidt. Sch. At., 9/15, 71/78. (See Pl. XXX, fig. 2.)

Cymbella amphicephala Naegeli. Sch. At., 9/56 (no name), 66.

Cymbella cuspidata Kuetzing. V. H. Syn., 2/3. Found together with very small and robust varieties.

Cymbella lunula (Ehrenberg) Rabenhorst. Sch. At., 10/42–43. The variety found in the Spokane area approaches *C. ventricosa* Kuetzing, with which this species is sometimes united.

Cymbella partita Mann, n. sp. (See Pl. XXXI, fig. 1.)

Cymbella sagittarius Mann, n. sp. (See Pl. XXXI, fig. 2.)

Desmogonium raberhorstianum Grunow. Sch. At., 293/1–11.

Diatoma grande W. Smith. S. B. D., 40/310. Perhaps this is a variety of *D. vulgare* Bory.

Diatoma tenue var. *hybrida* Grunow. V. H. Syn., 50/10–13.

Diatoma vulgare Bory, type form. Sch. At., 268/24.

Diatoma vulgare var. *ehrenbergii* Grunow. Sch. At., 268/36.

Eunotia faba (Ehrenberg) Grunow. Sch. At., 270/33–41.

Eunotia gracilis (Ehrenberg) Rabenhorst. (See Pl. XXX, fig. 3.) V. H. Syn., 33/1–2. Shows several interesting malformations.

Eunotia incisa Gregory. V. H. Syn., 34/35a.

Eunotia minor (Kuetzing) Rabenhorst. V. H. Syn., 33/20–21.

Eunotia parallela Ehrenberg. V. H. Syn., 34/16. Perhaps this is a variety of the next.

Eunotia pectinalis (Kuetzing) Rabenhorst. V. H. Syn., 33/15–16.

Eunotia robusta var. *diadema* (Ehrenberg) Ralfs. V. H. Syn., 33/12.

Eunotia robusta var. *papilio* Grunow. V. H. Syn., 33/8.

Fragilaria undata W. Smith. S. B. D., 60/377.

Frustulia rhomboides (Ehrenberg) De Toni. (See Pl. XXXI, fig. 3.) V. H. Syn., 17/1–2 (misnamed).

Gomphonema acuminatum var. *suecica* Grunow. V. H. Syn., 23/32 (misnamed). This is essentially the same as *G. acuminatum* var. *turris* Ehrenberg in Sch. At., 239/34.

Gomphonema gracile Ehrenberg. Sch. At., 236/16–30, especially fig. 20.

Gomphonema parvulum Kuetzing. V. H. Syn., 25/10.

Melosira biseriata Ehrenberg. Sch. At., 180/22.

Melosira distans Kuetzing. Sch. At., 181/7–11.

Melosira granulata (Ehrenberg) Ralfs. Sch. At., 181/63.

Melosira granulata var. = *M. crenulata* var. *tenuis* in Sch. At., 181/56.

Melosira lyrata Grunow. Sch. At., 181/75.

Melosira teres Brun? Sch. At., 179/13. Whether or not this is Brun's diatom is somewhat uncertain. The reference for the type merely says that it occurs in "Maine"; but where, and whether recent or fossil, marine or fresh water, is not stated.

Melosira undulata (Ehrenberg) Kuetzing. Sch. At., 180/6–9.

Navicula americana Ehrenberg. V. H. Syn., 12/37. Both the typical form and a narrow variety occur here.

Navicula amphigomphus Ehrenberg. Sch. At., 49/33–34. A species sometimes but unwisely united with *N. iridis* Ehrenberg.

Navicula angusta Grunow. V. H. Syn., 7/17.

Navicula bacillum Ehrenberg. V. H. Syn., 13/8. A variety occurs here that lacks the typical hyaline apical area.

Navicula commutata Grunow. Sch. At., 45/37.

Navicula contendens Mann, n. sp. (See Pl. XXXI, fig. 4.)

Navicula dubia Ehrenberg. (See *N. iridis* var. *dubia*.)

Navicula elegans W. Smith. S. B. D., 16/137; Donk. Brit. Diat., 4/1.

Navicula formosa Gregory. Sch. At., 50/14–15. Also a variety approaching *N. subsalina* Donkin. V. H. Syn., 11/6.

Navicula gibba (Ehrenberg) Donkin. S. B. D., 19/180; Sch. At., 45/50. This species should not be united with *N. stauroptera* Grunow, which see.

Navicula gracillima (Gregory) Schmidt. (See Pl. XXX, fig. 4.) Sch. At., 45/62. The specimens found agree closely enough for specific union with the illustration cited, but there is doubt if the name is correctly assigned. Gregory's species has no stauros. But the name is preferable to *N. mesolepta* var. *angusta*, which Cleve offers as a substitute.

Navicula hilseana (Janisch) Schmidt. Sch. At., 45/65. Twin forms of this species are common in the Spokane material.

Navicula instabilis Schmidt. Sch. At., 43/36. Twin forms of this also occur here. The species is close to *N. hemiptera* Kuetzing.

Navicula iridescens Mann, n. sp. (See Pl. XXX, fig. 5.)

Navicula iridis Ehrenberg var. *subampliata* Grunow. (See Pl. XXXI, fig. 5.) Sch. At., 49/19.

Navicula iridis Ehrenberg var. = *N. dubia* Ehrenberg in Sch. At., 49/7 and Donk. Brit. Diat. 5/5. The doubt expressed in Ehrenberg's specific name is justified, the form being merely a variety of *N. iridis*. Another variety that occurs here is something like *N. bisulcata* Lagerstedt in Sch. At., 49/15, but is much more delicate, narrow, and finely marked and measures only 0.091 millimeter in length and 0.013 millimeter in width.

Navicula major Grunow. Sch. At., 42/10. The true type form has not been found in the Spokane material, but there are two varieties, one with a very narrow median area and one intermediate between this species and *N. viridis* (Nitzsch) Kuetzing.

Navicula mesotyla (Ehrenberg) J. Schumann. Sch. At., 45/54–55.

Navicula nodosa Kuetzing. Sch. At., 45/56–58.

Navicula pauper Mann., n. sp. (See Pl. XXXI, fig. 6.)

Navicula placentula Ehrenberg. V. H. Syn., 8/26, 28.

Navicula pontifica Mann n. sp. (See Pl. XXXI, fig. 7.)

Navicula protrudens Mann, n. sp. (See Pl. XXXI, fig. 8.)

Navicula pseudo-affinis Mann, n. sp. (See Pl. XXX, fig. 6.)

Navicula pseudo-bacillum Grunow. V. H. Syn., 13/9.

Navicula pusilla W. Smith. S. B. D., 17/145. The specimens vary slightly from the type form.

Navicula radiosa Kuetzing. Sch. At., 47/52. Nearly all the specimens are modified into twin forms.

Navicula reversa Mann, n. sp. (See Pl. XXX, fig. 7.)

Navicula rupestris (Hantzsch) Schmidt. Sch. At., 45/38–44. Malformations and twin forms of this species were found abundantly.

Navicula scutiformis Grunow. Sch. At., 70/62. This species has not been found in America before. It occurs at Stavanger, Norway, and in a fossil deposit at Umca, Sweden. It is abundant here and affords several varieties.

Navicula stauroptera Grunow. Sch. At., 44/41.

Navicula stauroptera var. = *N. parva* (Ehrenberg) Van Heurck, in V. H. Syn., 6/6 (misnamed). The species should be kept separate from *N. gibba* (Ehrenberg) Donkin, which see.

Navicula subacuta (Ehrenberg) Schmidt. Sch. At., 43/31

Navicula substauroneis Mann, n. sp. (See Pl. XXXI, fig. 9.)

Navicula tabellaria (Ehrenberg) Kuetzing. Sch. At., 43/4.

Navicula transversa Schmidt. Sch. At., 43/5. The typical form occurs and a variety passing into *N. major* Grunow, to which this species is rather too close.

Navicula viridis (Nitzsch) Kuetzing. Sch. At., 42/13. Twin specimens are not uncommon.

Stauroneis (*Navicula*) *acutissima* Mann, n. sp. (See Pl. XXX, fig. 8.)

Stauroneis (*Navicula*) *anceps* Ehrenberg. Sch. At., 242/11–12. (See Pl. XXXI, fig. 11.)

Stauroneis (*Navicula*) *phoenicenteron* Ehrenberg. (See Pl. XXXI, fig. 12.) V. H. Syn., 4/2; Sch. At., 242/16. Nearly all specimens of this and the foregoing species were twin forms.

Surirella bifrons Kuetzing. Sch. At., 22/12.

Surirella inducta Schmidt, var. Sch. At., 24/25.

Surirella striatula Turpin. Sch. At., 24/20. This species seems to flourish in waters high in mineral content. It often holds its place in lakes that show a gradual increase in salinity after other species have been exterminated by the high percentage of salts. Thus in samples of borings made at the site of a prehistoric lake in the Black Rock district of Nevada, which slowly changed from fresh water to salt water, this species was the last diatom to succumb to the growing salinity. It is also sometimes the dominant species in such saline waters as Devils Lake, N. Dak., and Salt Lake, Utah.

Tabellaria binalis (Ehrenberg) Grunow. V. H. Syn., 44/23. The generic assignment of this well-known species is doubtful.

Tabellaria fenestrata Kuetzing. S. B. D., 43/317. Most of the specimens in the Spokane material are misshapen.

Tabellaria flocculosa (Roth) Kuetzing. S. B. D., 43/316.

Tetracyclus ellipticus (Ehrenberg) Grunow var. *latissima*. Sch. At., 281/20–23.

Tetracyclus ellipticus (Ehrenberg) Grunow var. *linearis*. Sch. At., 281/12.

Tetracyclus lacustris Ralfs. Sch. At., 269/7–8.

Tetracyclus rupestris (Brun) Grunow. Sch. At., 297/96, 101.

The new species are described below.

Cymbella partita Mann, n. sp.

Plate XXXI, Figure 1

Valve moderately bowed, its apices rounded, not bent upward or extended; the dorsal side evenly convex, the ventral barely convex and slightly enlarged at the middle; an unusually wide, hyaline median area, enlarged at the center, extends from that point straight to each apex, thereby exactly bisecting the valve, whence the specific name here given; rhaphe strong, straight, its central ends separated by the large central nodule, its apical ends also straight and entering the bulbous terminations of the median area; markings of fine closely set rows of beading, transverse to the median area. Length, average, 0.184 millimeter; width, 0.036 millimeter; 8 lines in 0.01 millimeter.

This species is near that phase of *C. gastroides* Kuetzing figured in Sch. At., 9/2, but is too wide to be grouped with it as a variety. It occurs in this material in both the normal and the twin conditions.

Cymbella sagittarius Mann, n. sp.

Plate XXXI, Figure 2

Valve with extended and acute ends, the dorsal side strongly convex in its middle part and rapidly tapering to the ends; the ventral side slightly convex from end to end; rhaphe median, straight; markings of very fine beaded rows, the beads so spaced as to show both transverse and longitudinal interlines; median area wide, tapering, distended at the middle, especially on the ventral side, where it nearly reaches the margin; central nodule prominent. Length, 0.114 millimeter; width, 0.022 millimeter; 16 lines in 0.01 millimeter.

This graceful and sharp-ended species is quite distinct from any known form. Its name refers to the perfect bow formed by the rhaphe and the dorsal margin.

Navicula contendens Mann, n. sp.

Plate XXXI, Figure 4

Valve fusiform, with slightly enlarged, rounded apices; markings of strong, closely set moniliform costae, radial at the middle of the valve, reversed near and at the apices; hyaline median area widely distended at the middle of the valve, tapering to near the apices, where the markings closely approach the rhaphe; outer ends of the rhaphe slightly hooked and surrounded by small hyaline areas, middle ends of the rhaphe bent to one side. Length, 0.078 millimeter; width, 0.0194 millimeter; 11.5 lines in 0.01 millimeter.

This species resembles the one figured in V. H. Syn., 6/17, incorrectly named as a variety of *N. legumen* Ehrenberg. Cleve (Nav. Diat., II, p. 84) groups it with the similar form in Sch. At., 45/30, the less similar form in Sch. At., 45/29, and *N. scythica* Pantocsek in Pant. Hung. Diat., III, 23/335, under *Pinnularia subsolaris* Grunow. Although the figure in Sch. At., 45/30, might be united with the others above mentioned, the species here represented is too dissimilar to admit of the same assignment.

Navicula iridescens Mann, n. sp.

Plate XXX, Figure 5

Valve delicate, narrow, spindle-shaped, with slightly protruding ends that are capped at the tip with a lunate thickening, like the other members of the *N. iridis* group; markings of fine, closely set beaded lines, transverse and reaching close to the rhaphe, except at the center, where there is a small diamond-shaped area; a single wavy line close to each side traverses the entire length of the valve; rhaphe perfectly straight, not bent on hooked at the center. Length, 0.128 millimeter; width, 0.021 millimeter; 22 lines in 0.01 millimeter. It has a remote resemblance to the unnamed form shown in Sch. At., 49/40.

Navicula pauper Mann, n. sp.

Plate XXXI, Figure 6

Valve narrow, almost linear, slightly tapered to the blunt, enlarged ends, which are thickened internally into a lunate cap, characteristic of the *N. iridis* group; markings confined to a narrow, somewhat ragged band of fine, beaded, transverse lines along each side, the beads on the inner edge of each band being larger than the rest; rhaphe strong, straight, its middle ends not bent or enlarged. Length, average, 0.110 millimeter; width, 0.016 millimeter; 7 lines in 0.01 millimeter. The specimens showed many cases of malformation and twin forming.

Navicula pontifica Mann, n. sp.

Plate XXXI, Figure 7

Valve elongated, robust, barely tapering from the slightly distended middle to the rounded ends; markings of strong, smooth costal lines, radially oblique at the middle and halfway to the ends, then reversed oblique, reduced to mere traces at the ends and wanting at the middle, thereby producing a broad, somewhat flaring stauros; a single wavy line runs the length of the valve on either side close to the margin; longitudinal median area fully one-third the width of the valve, dilated at the ends; rhaphe straight, its central ends slightly bent, its apical ends strongly hooked. Length, 0.189 millimeter; width, 0.026 millimeter; 10 lines in 0.01 millimeter. Distinguished from minute specimens of *N. major* readily by its strong stauros.

Navicula protrudens Mann, n. sp.

Plate XXXI, Figure 8

Valve very convex, narrow, elongated, dilated at the middle, otherwise straight, with rounded, not swollen ends; markings of fine, transverse, beaded lines, reaching almost to the rhaphe except at the middle, where there is a large diamond-shaped median area; a strong, longitudinal line running midway between the rhaphe and each side; rhaphe straight, its outer ends terminating in large protuberant beads, whence the specific name. Length, average, 0.082 millimeter; width, 0.012 millimeter; 9 lines in 0.01 millimeter.

Navicula pseudo-affinis Mann, n. sp.

Plate XXX, Figure 6

Valve elongated, gently narrowed from the middle to near the ends, then abruptly compressed, so that the last part at each end is protuberant, with wedge-shaped apex; markings of fine and closely set rows of slightly elongated beads, the rows radial at the center and oblique to near each end, where they become transverse, not reaching inward to the rhaphe line, but leaving a wide longitudinal median area, dilated at the center of the valve; a distinct line running longitudinally on each side near the margin until the two merge into the two forks extending inward from a hyaline area at each apex of the valve; rhaphe strong, straight, its inner ends bent into minute hooks, both turned toward the same side. Length, 0.168 millimeter; width, 0.031 millimeter; 12 lines in 0.01 millimeter.

The nearest relatives are the unnamed form shown in Sch. At., 49/1, called *N. affinis* var. *genuina* Cleve in Fricke's index of that work; also fig. 19 on the same plate, having the questionable name *N. firma* var. *subampliata* Grunow. But both differ from this species in the direction and composition of their markings.

Navicula reversa Mann, n. sp.

Plate XXX, Figure 7

Valve broad, stout, with practically parallel sides and rounded ends; marked with closely set and fine beading in strongly divergent, wavy rows at the middle, which continue radially oblique to near the ends, then reversing to strongly convergently oblique, as in *N. oblonga* Kuetzing; central area large, rectangular, merging into a narrow median line running to the apices; rhaphe slightly undulate, its two middle ends joined across the central nodule by a thin line, its two terminal ends hooked. Length, 0.107 millimeter; width, 0.022 millimeter; 8 lines in 0.01 millimeter.

This approaches several known species but without sufficient nearness to warrant a union: *N. commutata* Grunow as figured in Sch. At., 45/35, and the variety of *N. major* Grunow shown in Sch. At., 42/8—a good illustration of how a species may serve as a bridge between two quite dissimilar forms. It stands even nearer to the form which Grunow calls *N. (Pinnularia) leptogonglya* Ehrenberg in Sch. At., 45/26 and which Schmidt there claims to be quite different, and rightly so. I have therefore found it convenient to assign a name.

Navicula substauroneis Mann, n. sp.

Plate XXXI, Figures 9, 10

Valve narrow, lanceolate, sides straight from the middle to the blunt, rounded ends; markings of strongly beaded lines, barely oblique to near the ends, there transverse, reaching nearly to the rhaphe but leaving an evident central area extended into a strong stauros across the middle to the sides; rhaphe delicate, its inner ends slightly bent and bead-tipped, its outer ends hooked. Length, average, 0.105 millimeter; width, 0.015 millimeter; 10 lines in 0.01 millimeter.

Stauroneis (Navicula) acutissima Mann, n. sp.

Plate XXX, Figures 8, 9

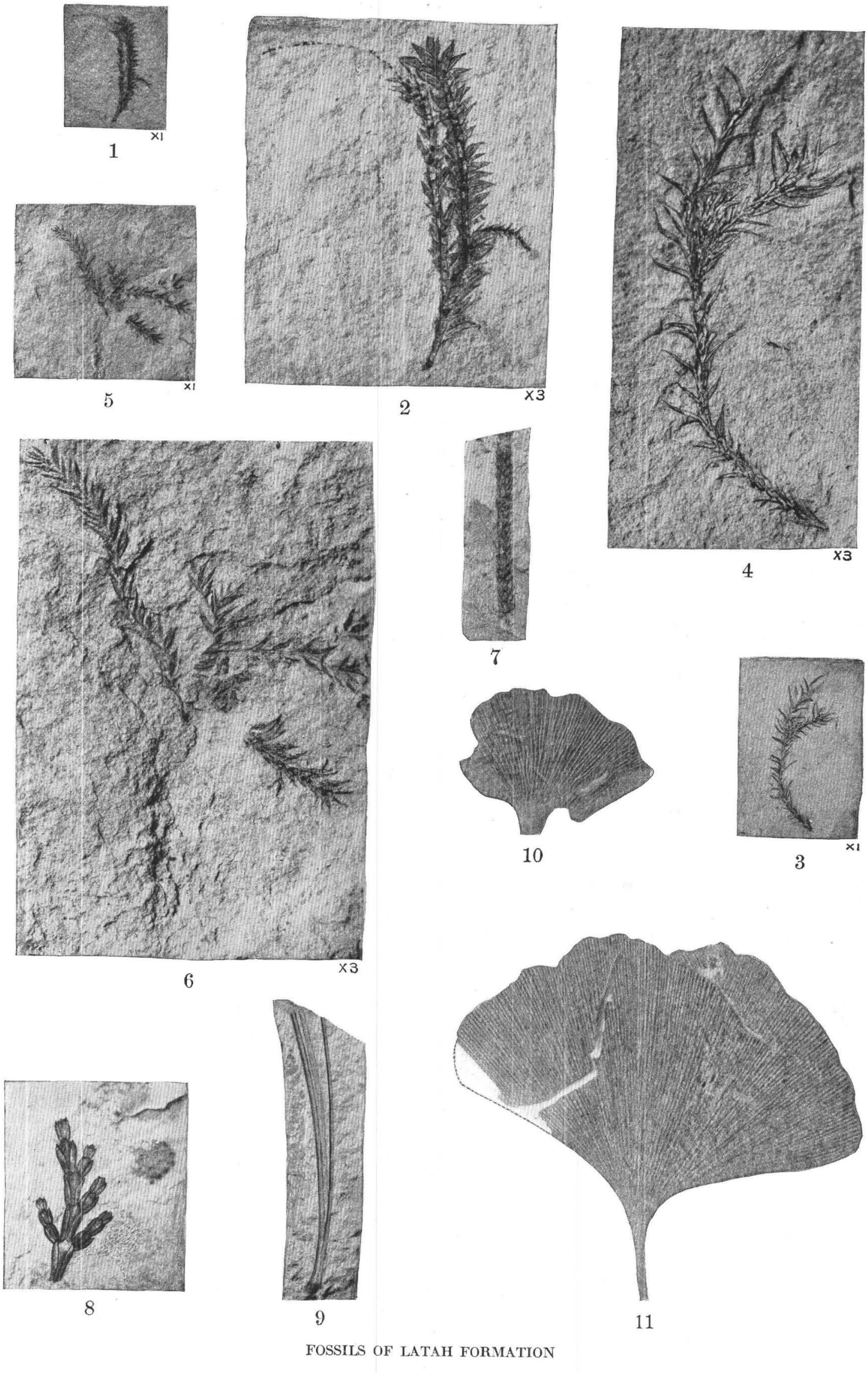
Valve narrow, lanceolate, with much elongated, needle-sharp ends and slightly undulate sides; markings of very fine, closely set beaded lines, somewhat radially oblique to the long axis, reaching from the sides to the rhaphe; a broad, slightly depressed stauros across the middle; rhaphe straight, delicate, each half beginning at the stauros and running to the extreme tip of the valve; the tips thickened internally as in *S. acuta* W. Smith, so that the inner cavity of the diatom is remote from the very pointed tips. Length, 0.070 millimeter; width, 0.010 millimeter; 29 lines in 0.01 millimeter.

It would be permissible to classify this as a very wide variety of *S. smithii* Grunow, but its larger size, much more acicular shape, and broad stauros are in favor of a separate name. Many malformed specimens were found, one of which is here illustrated.

PLATES VIII–XXXI

PLATE VIII

		Page
FIGURE 1.	*Archaeomnium patens* E. G. Britton. Cut No. 1, Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36869	24
2.	Same, × 3.	
3.	*Polytrichites spokanensis* E. G. Britton. Deep Creek northwest of Spokane, Wash. U. S. Nat. Mus. No. 36870	24
4.	Same, × 3.	
5.	Moss, genus and species? Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36871	24
6.	Same, × 3.	
7.	*Lycopodium hesperium* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36872	24
8.	*Libocedrus praedecurrens* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36873	28
9.	*Pinus* sp. Well near Mica, southeast of Spokane, Wash. U. S. Nat. Mus. No. 36874	26
10.	*Ginkgo adiantoides* (Unger) Heer. Third cut on Spokane, Portland & Seattle Railway, Spokane, Wash, U. S. Nat. Mus. No. 37192	25
11.	*Ginkgo adiantoides* (Unger) Heer. Fivemile Prairie, near Spokane, Wash. Specimen in Public Museum, Spokane	25



FOSSILS OF LATAH FORMATION

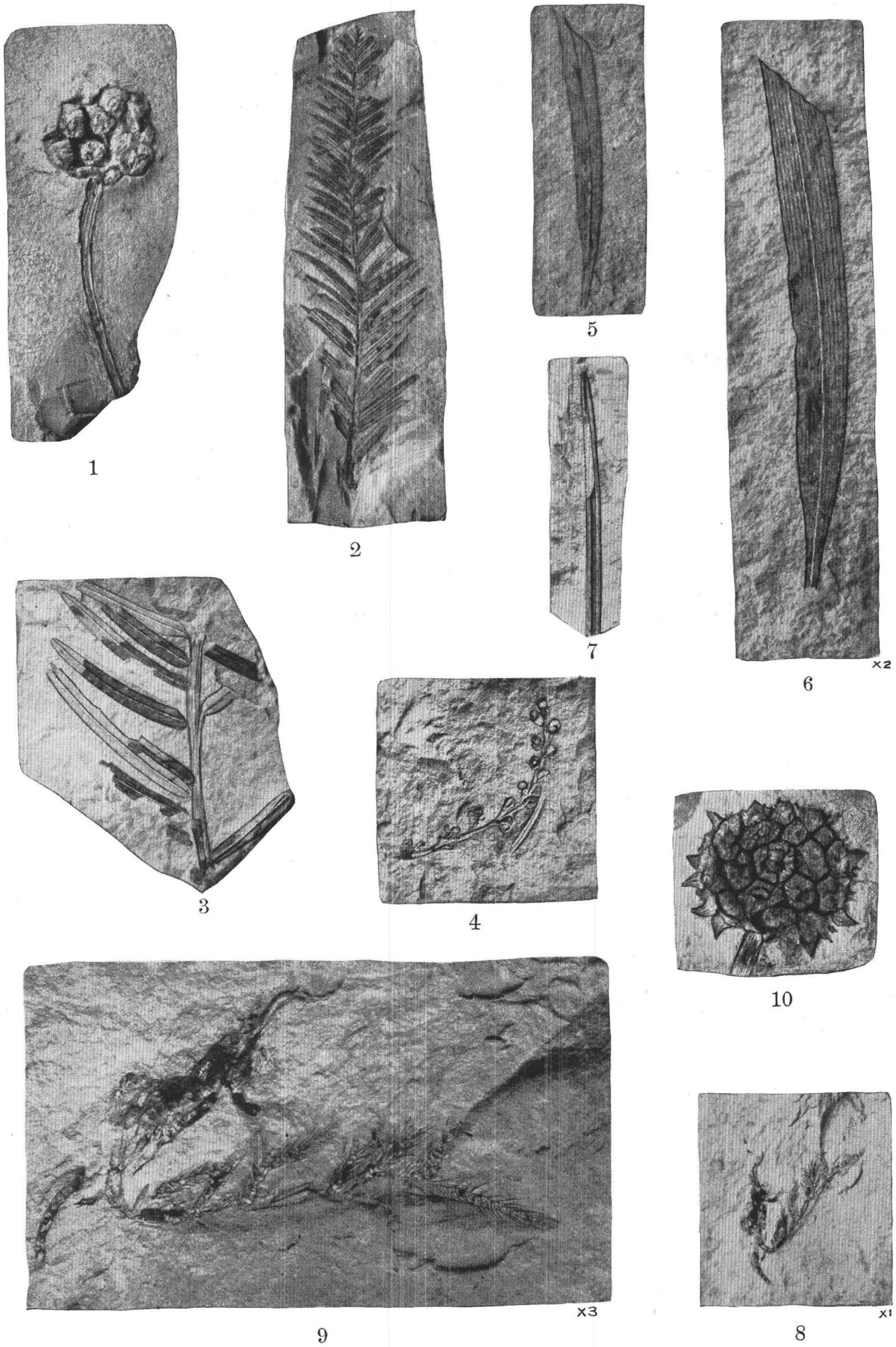
FOSSILS OF LATAH FORMATION

PLATE IX

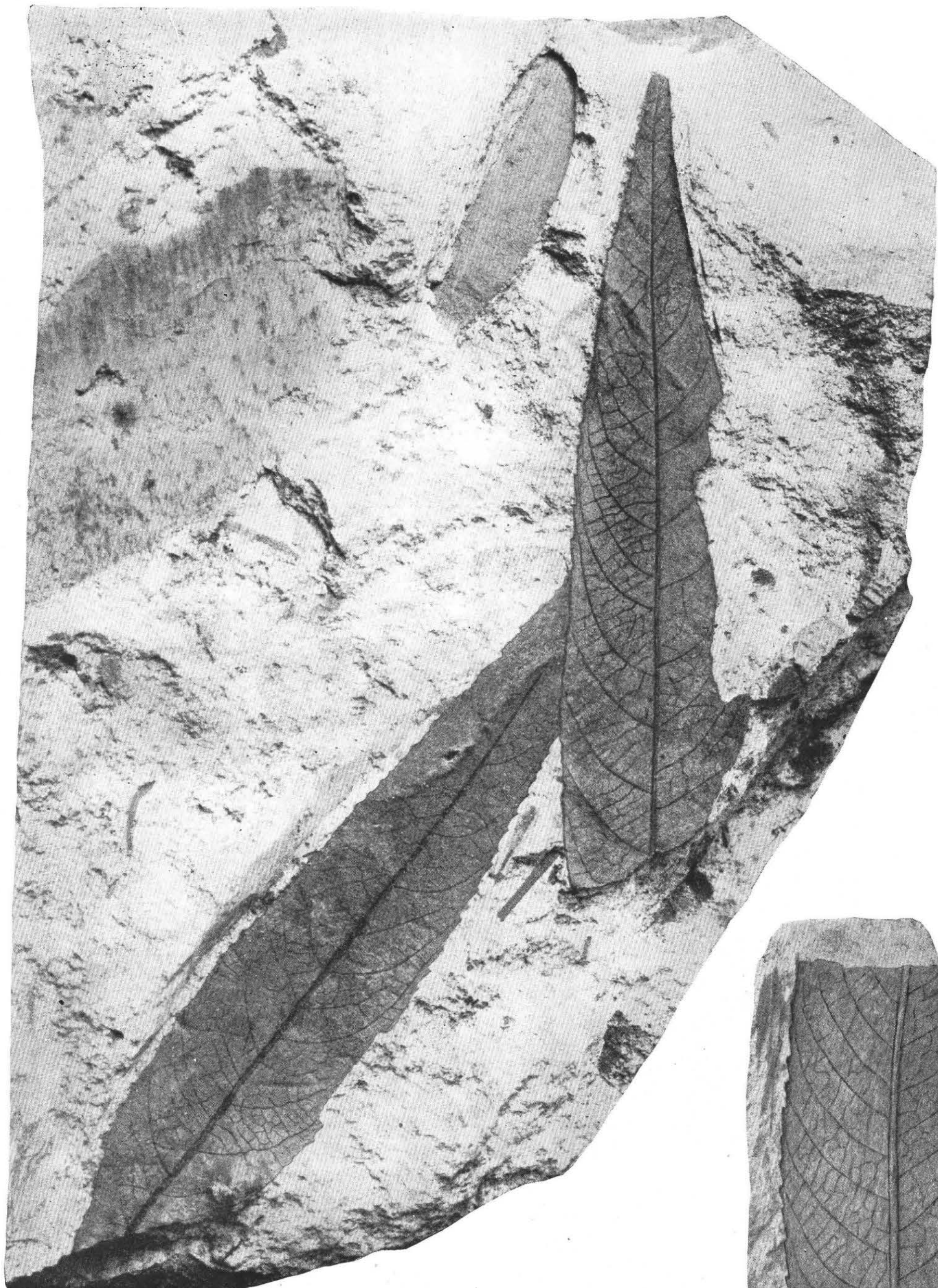
		Page
FIGURE 1.	*Equisetum*, underground stem. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36875	24
2.	*Taxodium dubium* (Sternberg) Heer. Deep Creek half a mile above mouth, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36876	27
3–6.	*Sequoia langsdorfii* (Brongniart) Heer. Figs. 3, 4, 5, from Deep Creek half a mile above mouth, northwest of Spokane, Wash. (U. S. Nat. Mus. Nos. 36880, 36881, 36882); fig. 6 from Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho (U. S. Nat. Mus. No. 36879)	26
7–9.	*Taxodium dubium* (Sternberg) Heer. Fig. 7 from Elko, Nev. (U. S. Nat. Mus. No. 36883) (introduced for comparison); fig. 8 from Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho (U. S. Nat. Mus. No. 36878); fig. 9 from cut on Spokane, Portland & Seattle Railway, Spokane, Wash. (U. S. Nat. Mus. No. 36877)	27
10.	Fern, fragment, × 2. Cut No. 2, Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash. U. S. Nat. Mus. No. 36884	24
11.	*Typha?* sp. Spokane, Wash. Specimen in University of California, No. $\frac{3940}{22843}$	28

PLATE X

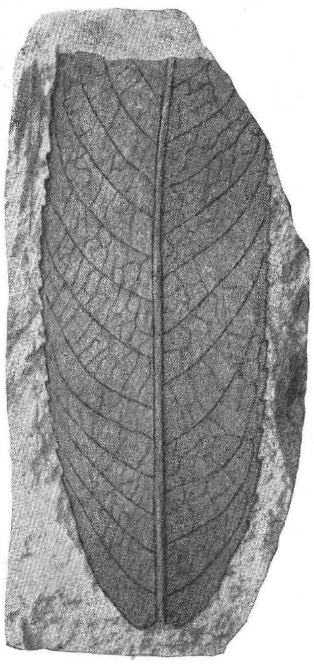
		Page
FIGURE	1. *Arisaema hesperia* Knowlton. Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36885	29
	2. *Taxodium dubium* (Sternberg) Heer. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36886	27
	3. *Tumion bonseri* Knowlton. Spokane, Wash. U. S. Nat. Mus. No. 36887	25
	4. *Taxodium*, male aments. Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36888	28
	5. *Potamogeton* sp. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36889	29
	6. Same, × 2.	
	7. Grass, leaf. Cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash. U. S. Nat. Mus. No. 36890	29
	8. Grass?, genus? Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36891	29
	9. Same, × 3.	
	10. *Liquidambar*, fruit, × 2. Cut No. 2, Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash. U. S. Nat. Mus. No. 36892	42



FOSSILS OF LATAH FORMATION



1



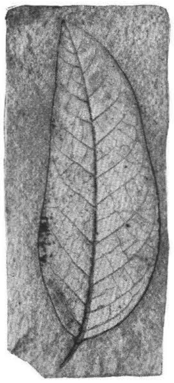
2

FOSSILS OF LATAH FORMATION

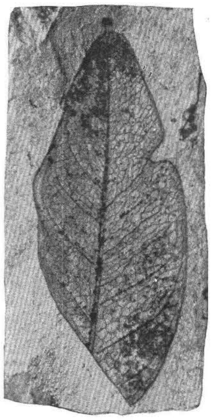
PLATE XI

PLATE XII

		Page
FIGURES 1, 2.	*Salix dayana* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. Nos. 36895, 36896	32
3.	*Salix* sp. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36897	33
4.	*Salix elongata* O. Weber. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36898	32
5.	*Salix perplexa* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36899	32
6.	*Salix bryani* Knowlton. Cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash. U. S. Nat. Mus. No. 36900	33
7.	*Salix remotidens* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36901	32
8–10.	*Populus heteromorpha* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. Nos. 36902, 36903, 36904	30

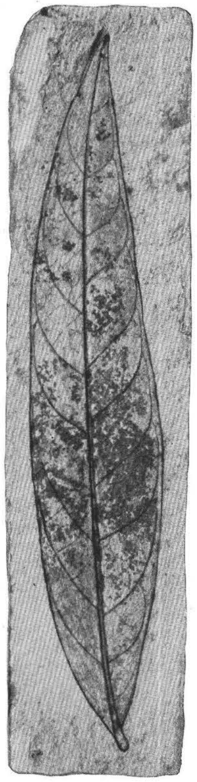


1

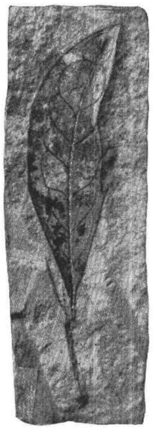


2

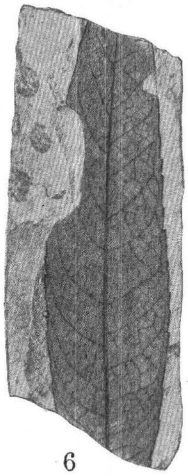
3



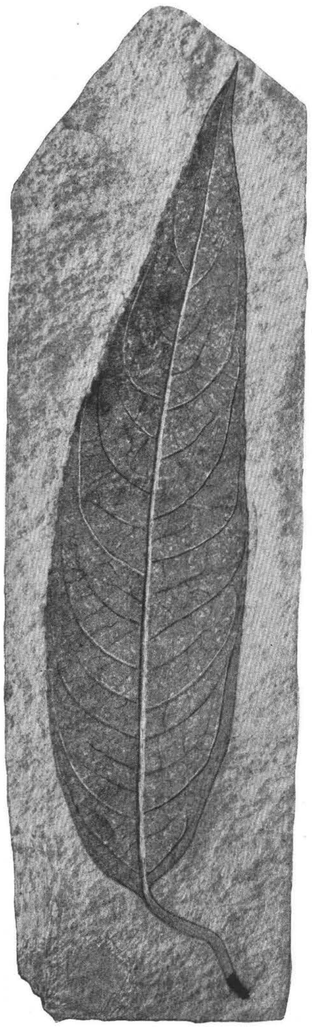
4



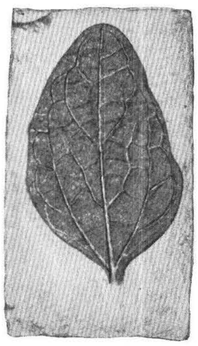
5



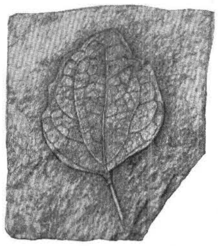
6



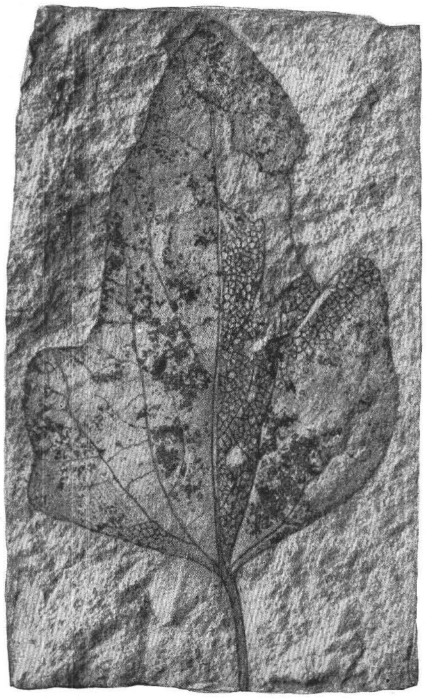
7



8

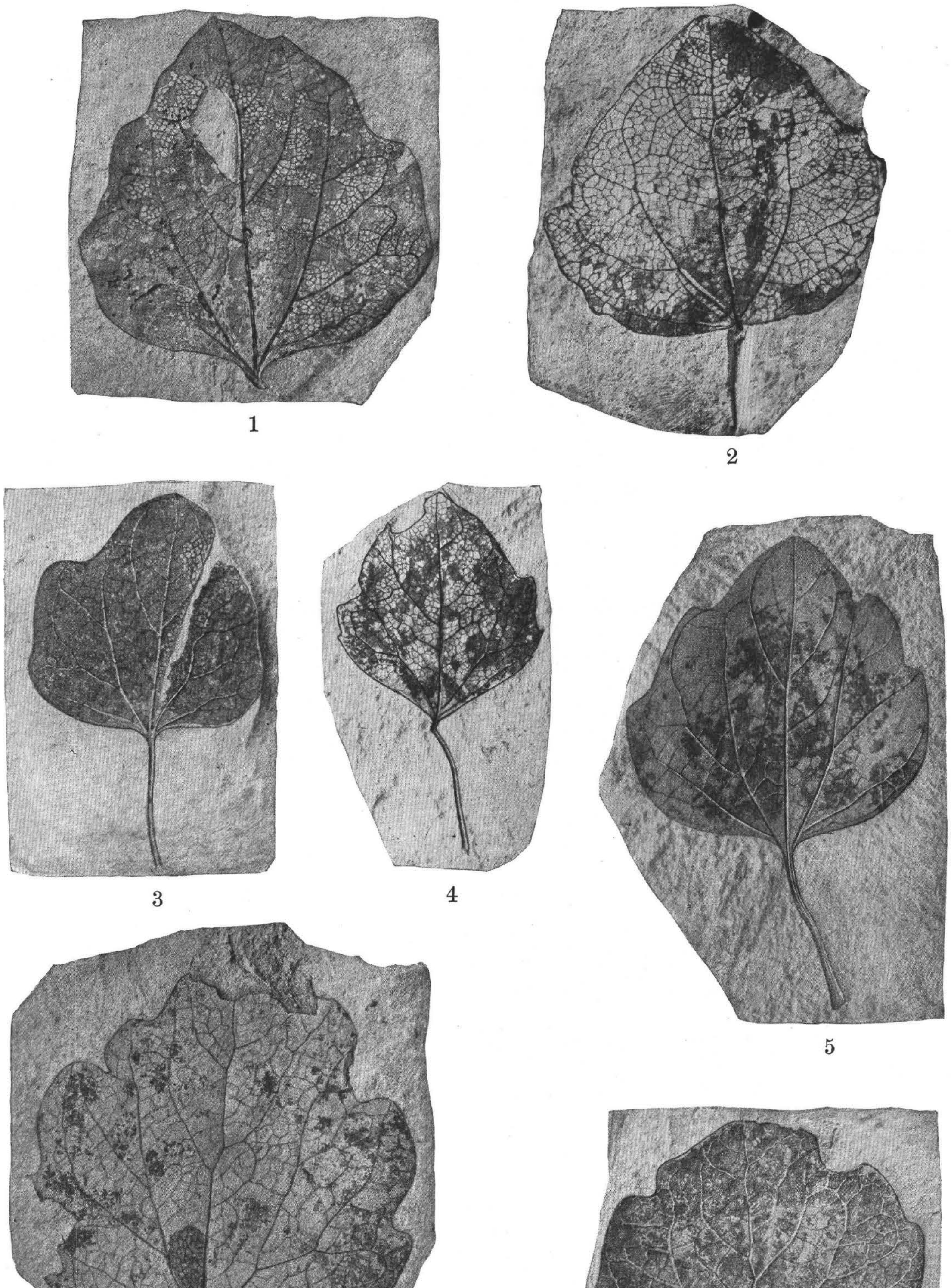


9



10

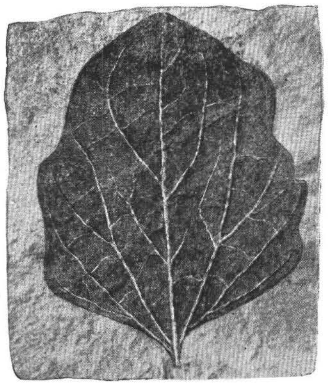
FOSSILS OF LATAH FORMATION



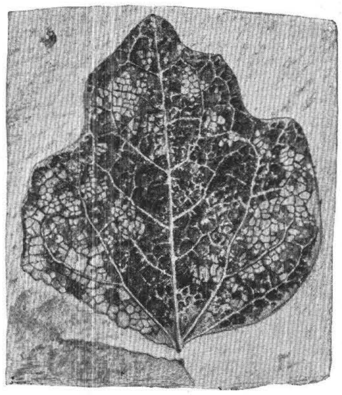
FOSSILS OF LATAH FORMATION

PLATE XIII

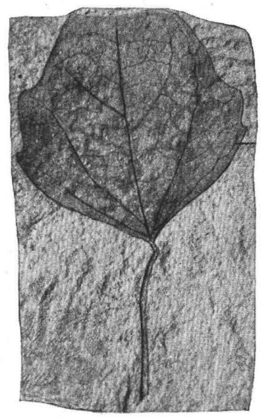
PLATE XIV



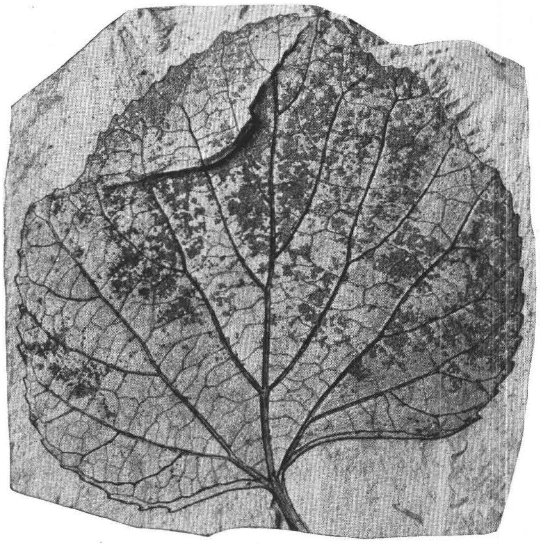
1



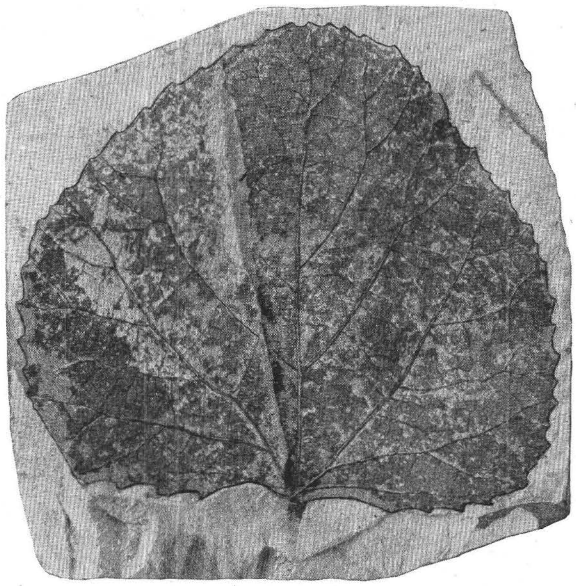
2



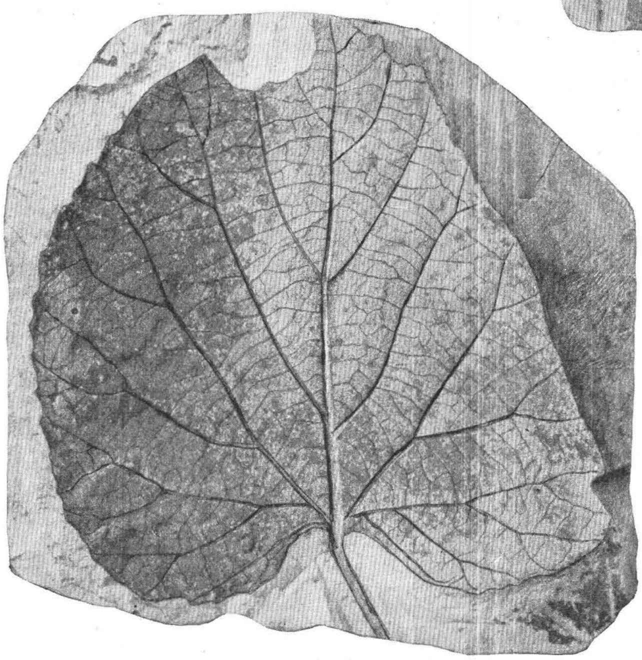
3



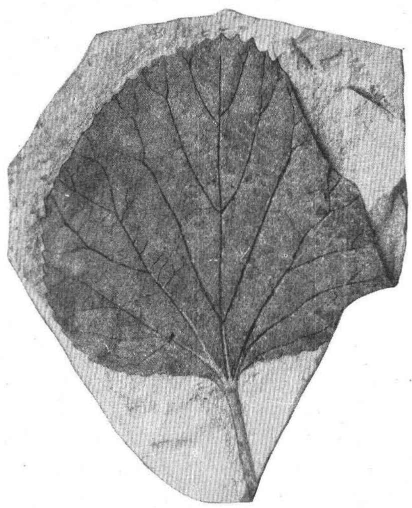
4



5

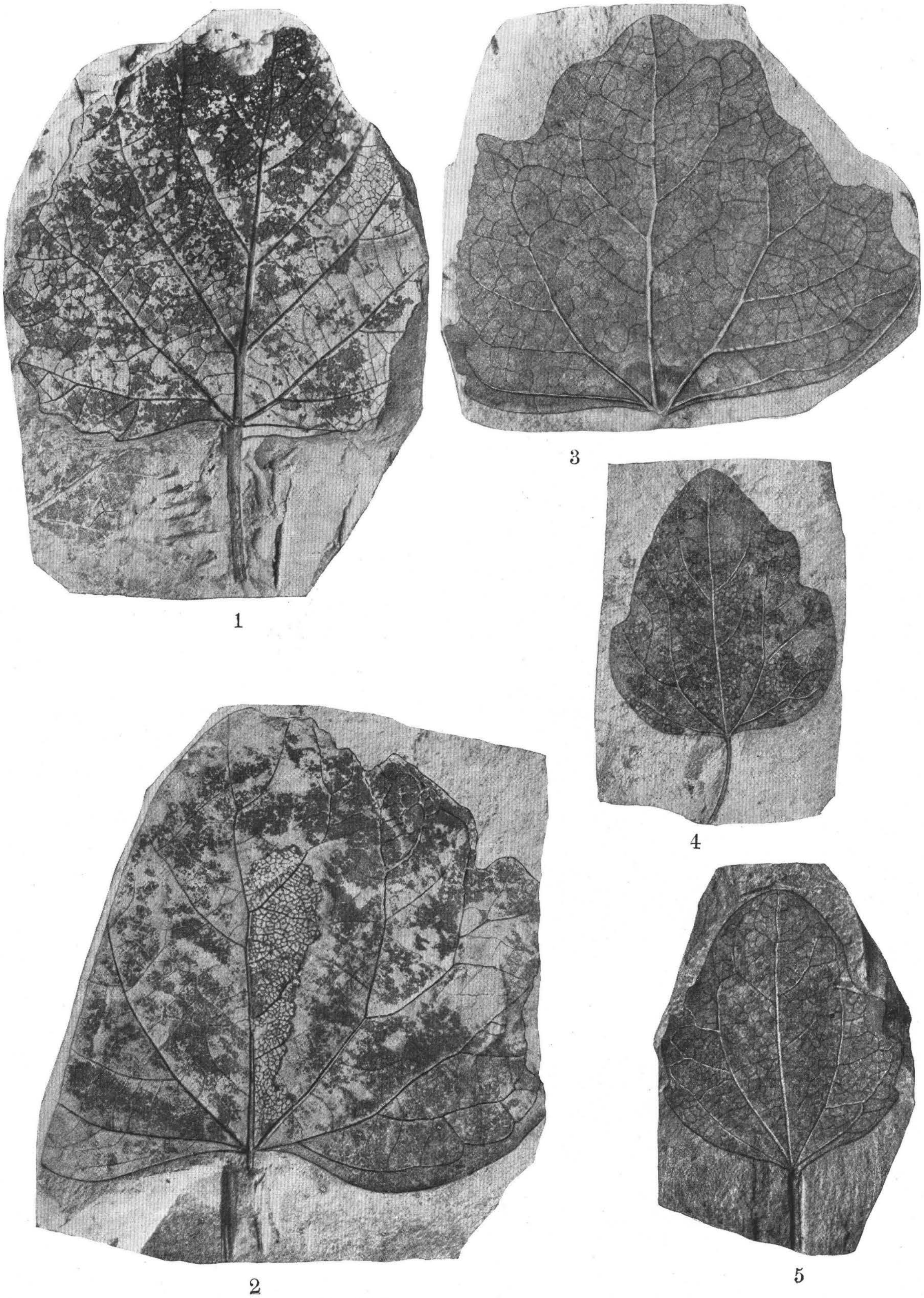


6



7

FOSSILS OF LATAH FORMATION



FOSSILS OF LATAH FORMATION

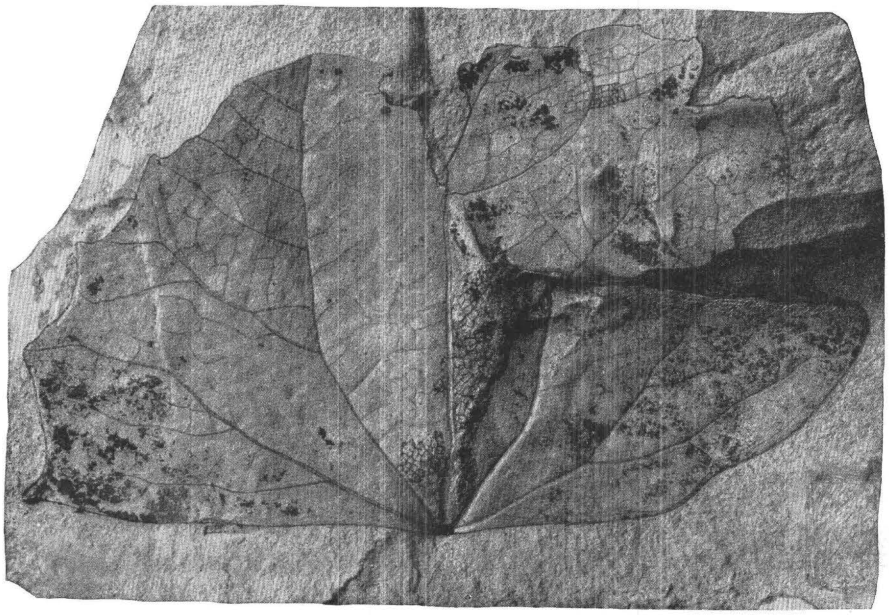
PLATE XV

		Page
FIGURE 1.	*Populus washingtonensis* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36919	31
2.	*Populus fairii* Knowlton. Spokane, Wash. U. S. Nat. Mus. No. 36920	30
3–5.	*Populus heteromorpha* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. Nos. 36921–36923	30

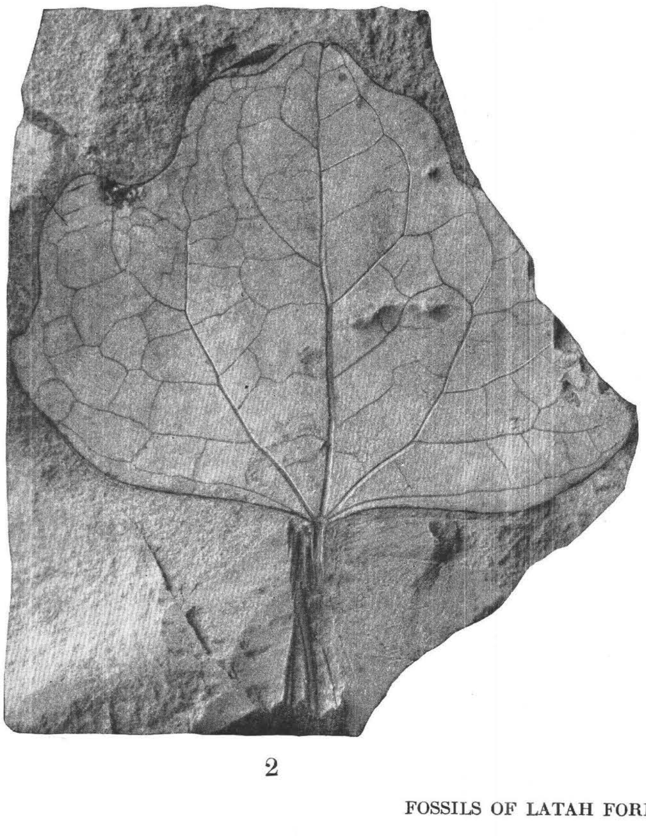
PLATE XVI

Page

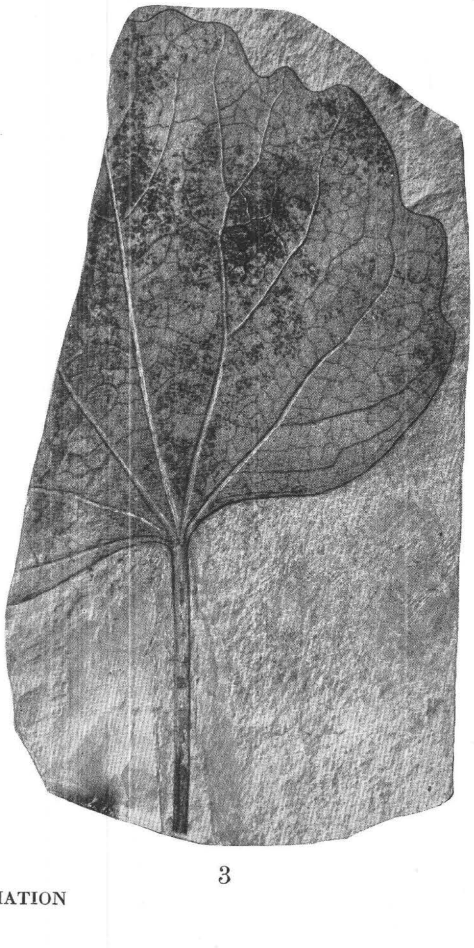
FIGURES 1–3. *Populus fairii* Knowlton. Spokane, Wash. U. S. Nat. Mus. Nos. 36924–36926 ---------------------------- 30



1

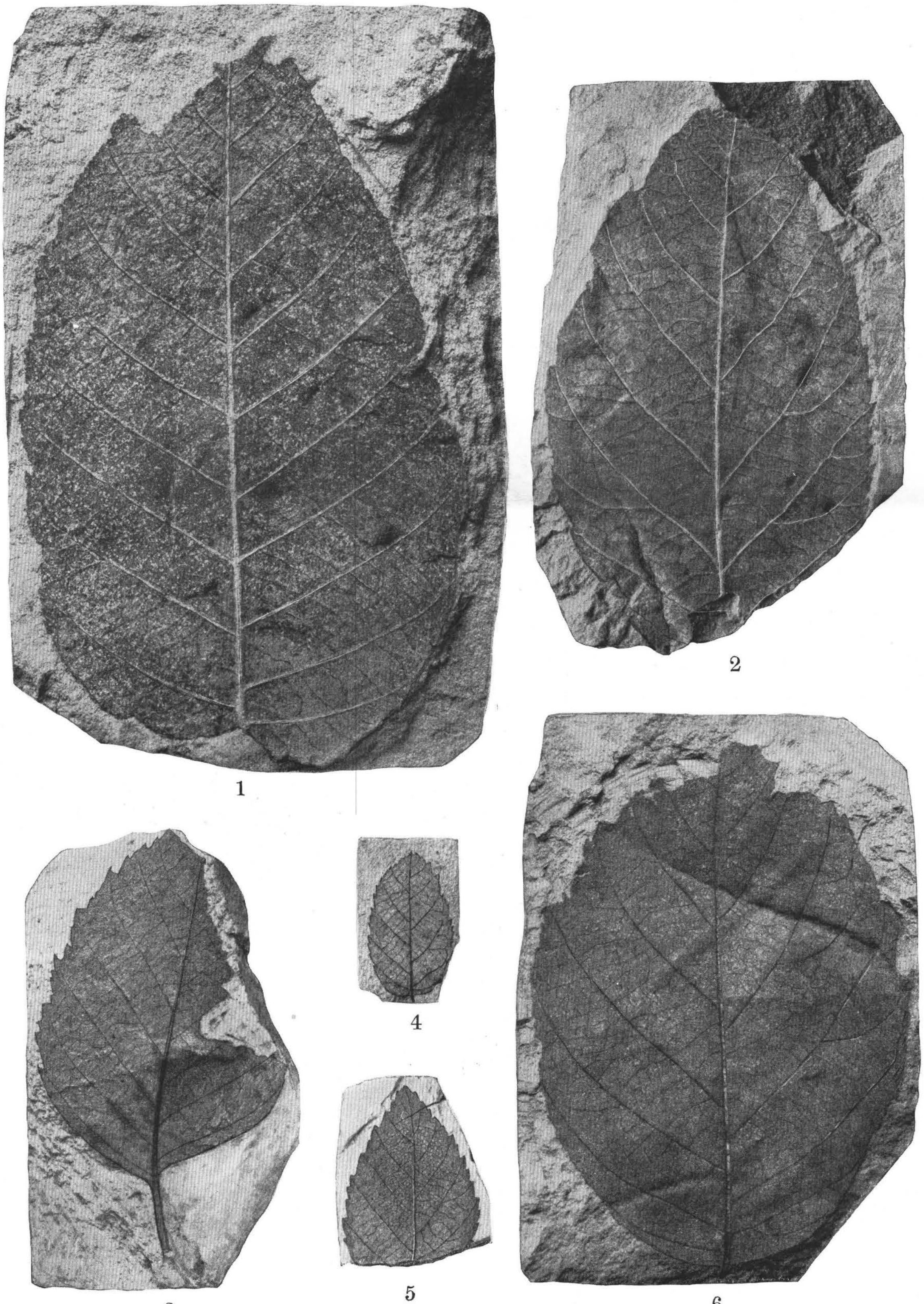


2



3

FOSSILS OF LATAH FORMATION



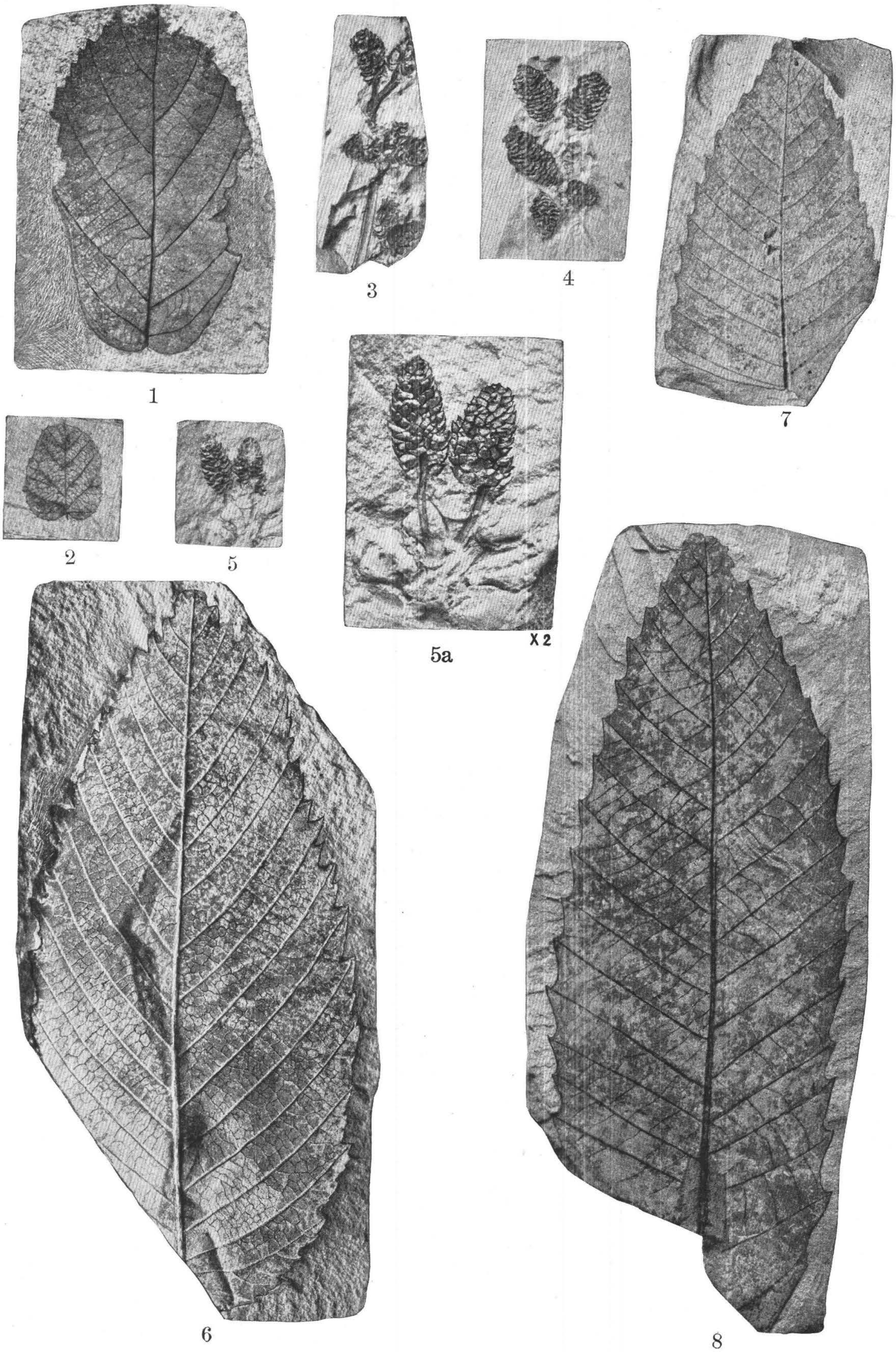
FOSSILS OF LATAH FORMATION

PLATE XVII

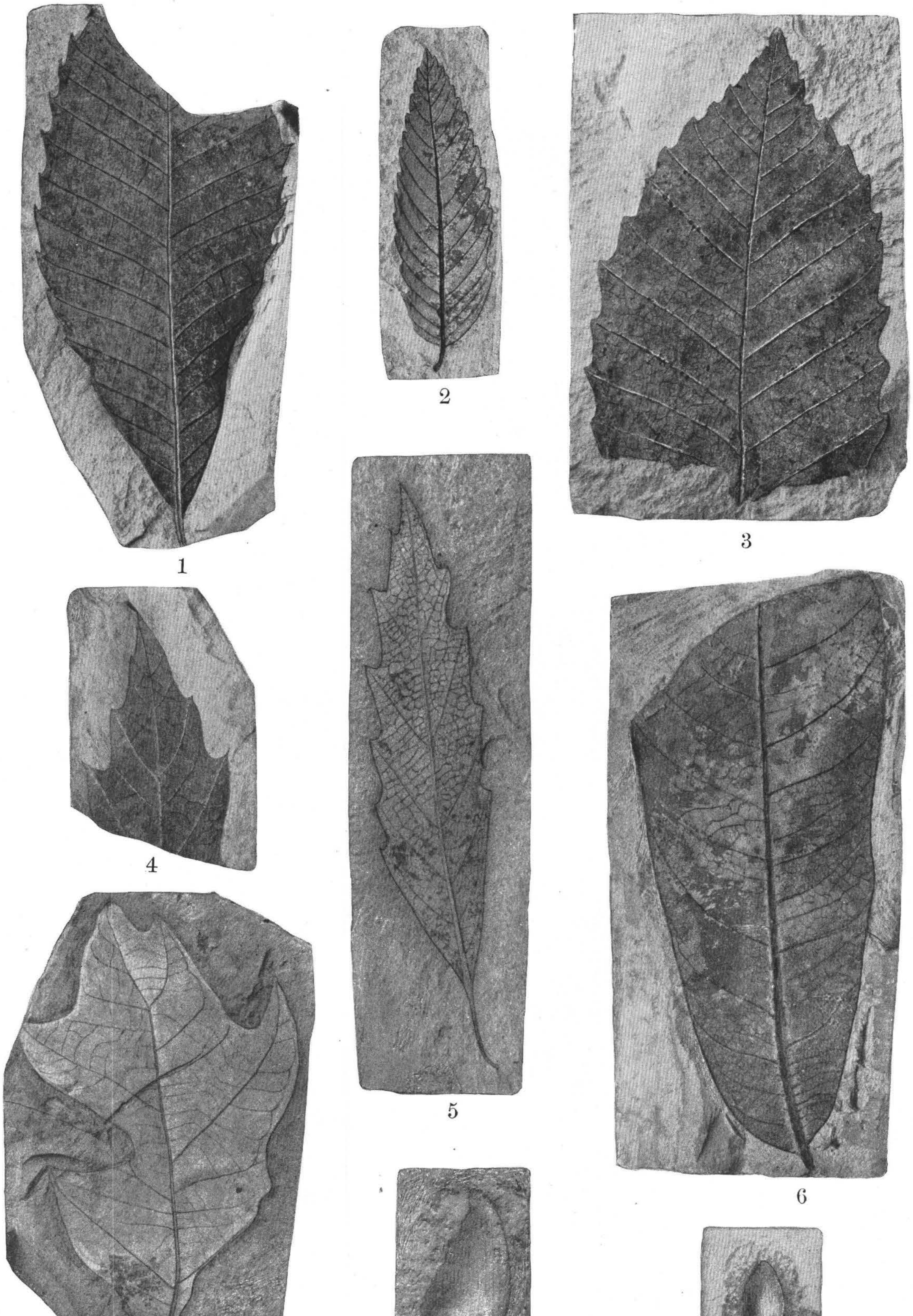
		Page
FIGURES 1, 2.	*Betula? largei* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. Nos. 36927, 36928	34
3.	*Betula thor* Knowlton. Twelfth Avenue and Thor Street, Spokane, Wash. U. S. Nat. Mus. No. 36929	35
4.	*Betula fairii* Knowlton. Cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash. U. S. Nat. Mus. No. 36930	33
5, 6.	*Betula heteromorpha* Knowlton. Fig. 5, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho (U. S. Nat. Mus. No. 36931). Fig. 6, Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. (U. S. Nat. Mus. No. 36932)	34

PLATE XVIII

		Page
FIGURE 1.	*Betula bryani* Knowlton. Twelfth Avenue and Thor Street, Spokane, Wash. U. S. Nat. Mus. No. 36933	34
2.	*Betula nanoides* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36934	34
3–5a.	*Alnus*; pistillate cones. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. Nos. 36935, 36936, 36937. Figure 5a twice enlarged	33
6.	*Ulmus speciosa* Newberry. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36938	39
7, 8.	*Castanea castaneaefolia* (Unger) Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. Nos. 36939, 36940	35



FOSSILS OF LATAH FORMATION

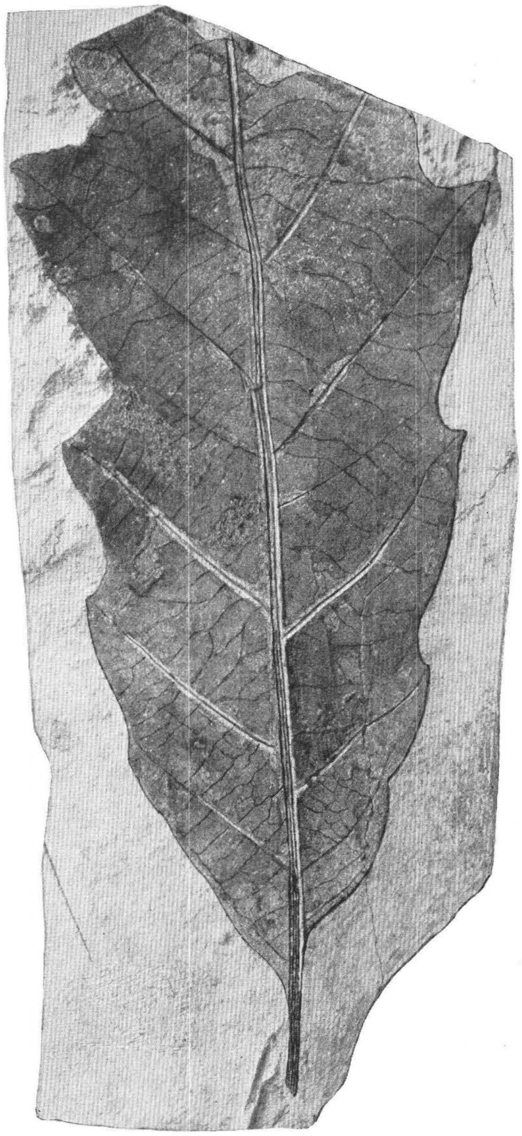


FOSSILS OF LATAH FORMATION

PLATE XIX

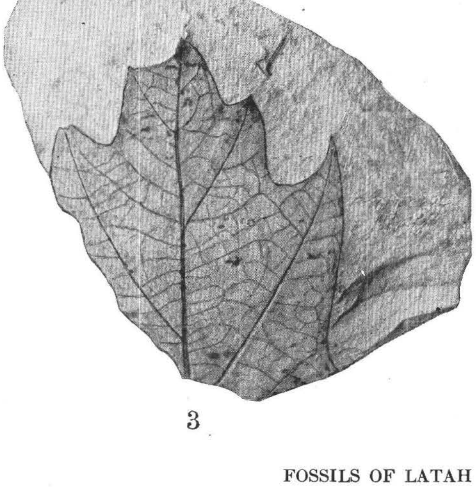
PLATE XX

	Page
FIGURES 1–4. *Quercus cognatus* Knowlton. Figures 1, 2, 4, Spokane, Wash.; Figure 3, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. Nos. 36949, 36950, 36951, 36952	36

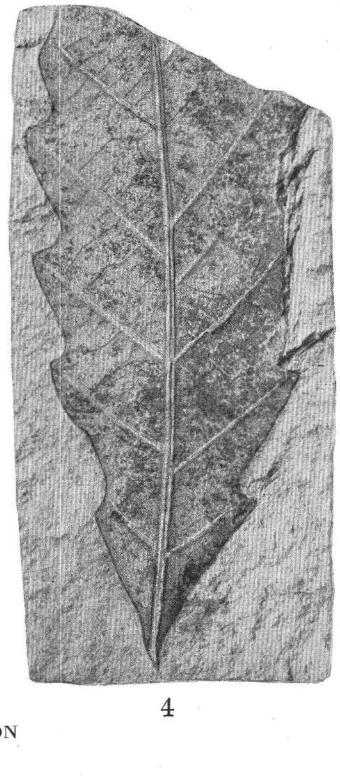


1

2

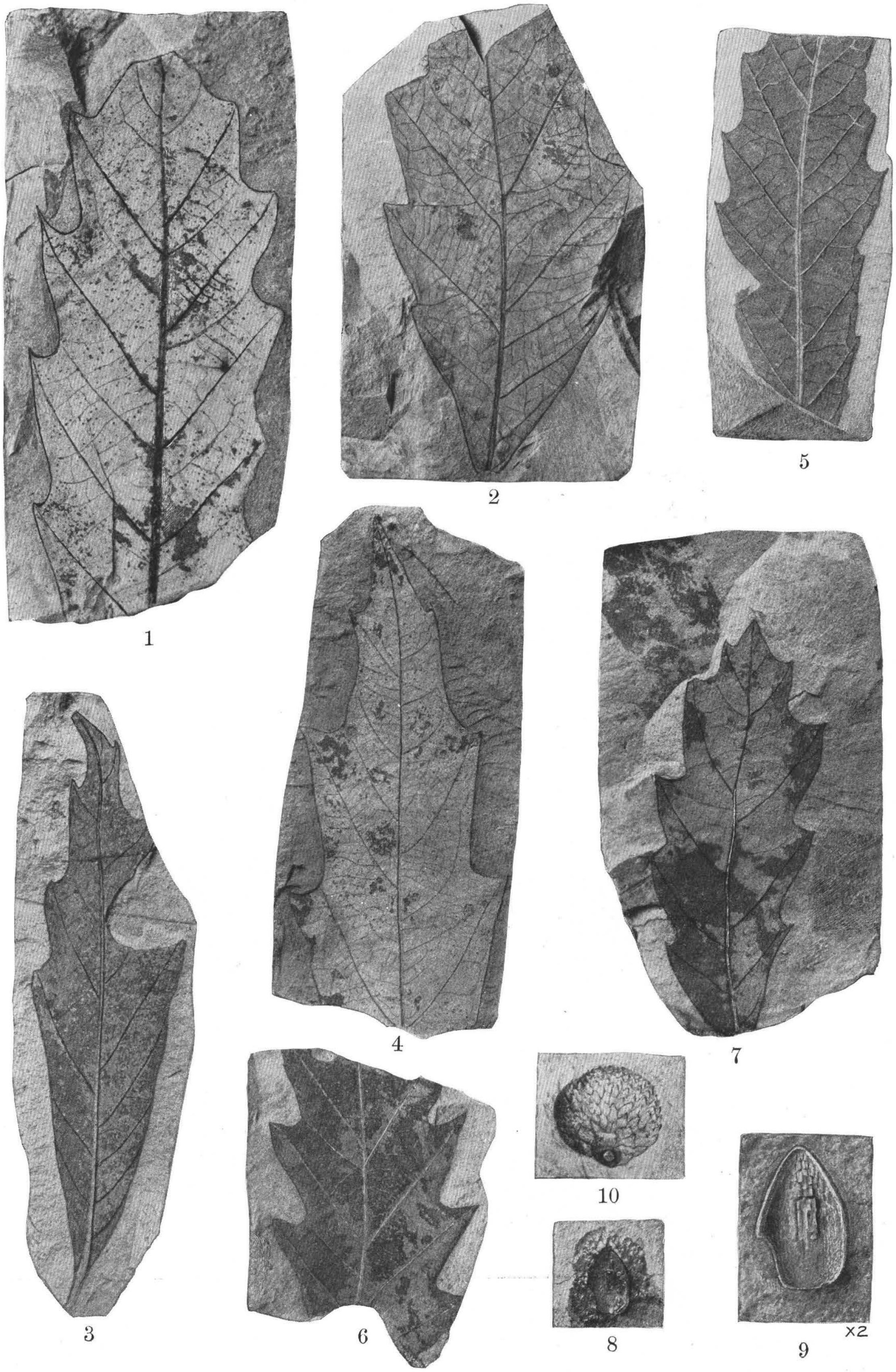


3



4

FOSSILS OF LATAH FORMATION



FOSSILS OF LATAH FORMATION

PLATE XXI

Page

FIGURES 1, 2. *Quercus cognatus* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho; Spokane, Wash. U. S. Nat. Mus. Nos. 36953, 36954 36

3, 4. *Quercus rustii* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. Nos. 36955, 36956 36

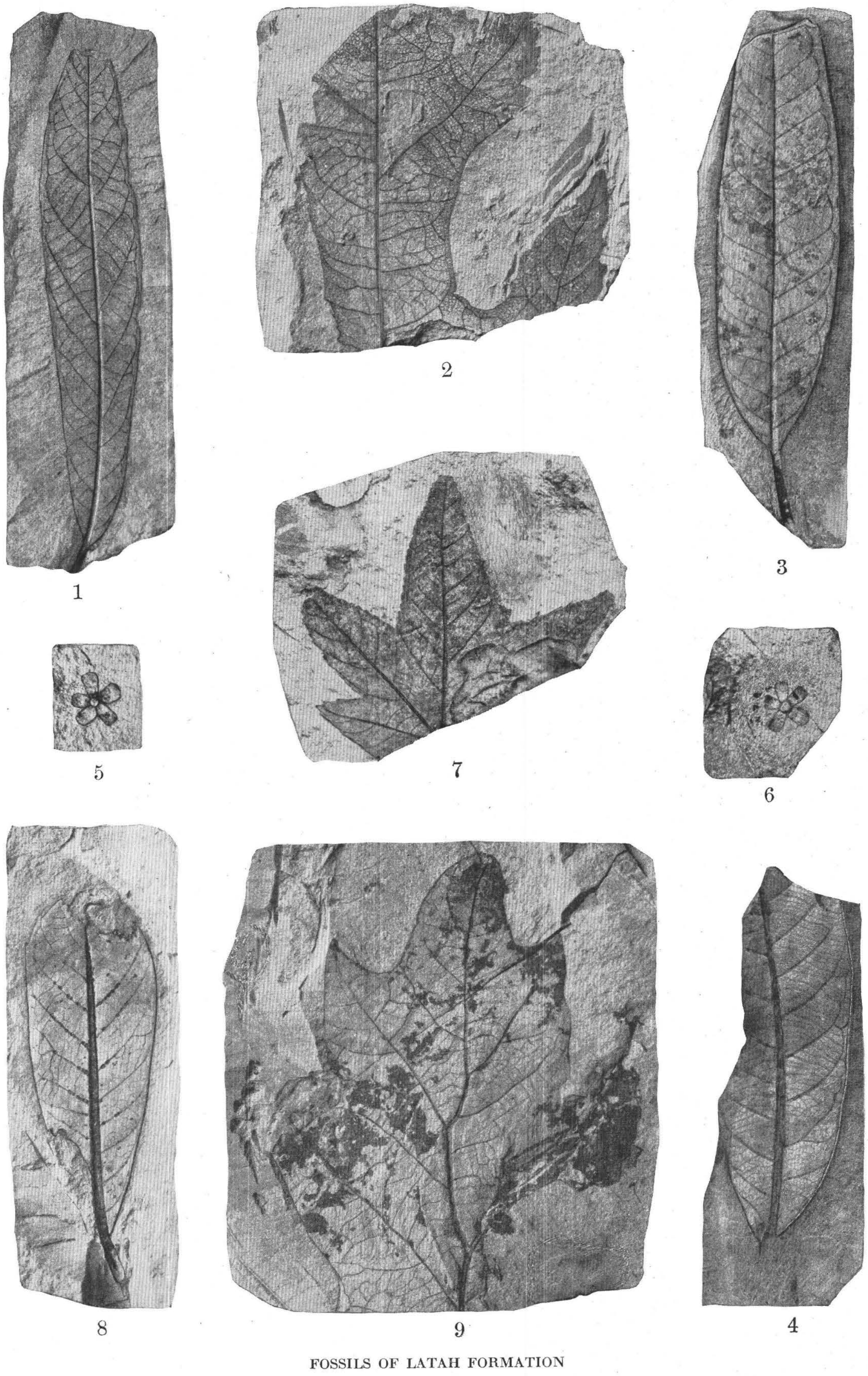
5–7. *Quercus payettensis* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. Nos. 36957, 36958, 36959 37

8. *Quercus*, acorn. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36961 39

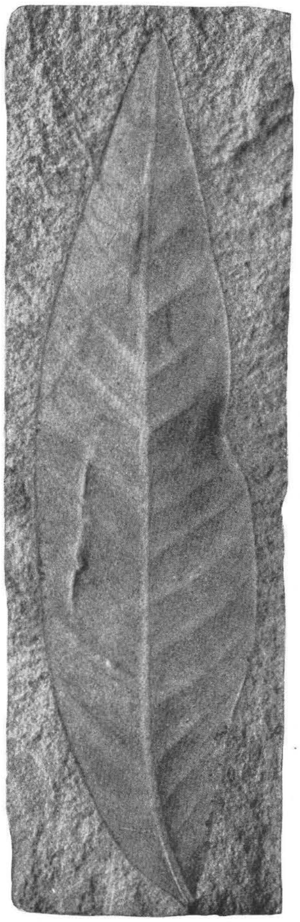
9. Same, × 2.

10. *Quercus*, cup. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36960 39

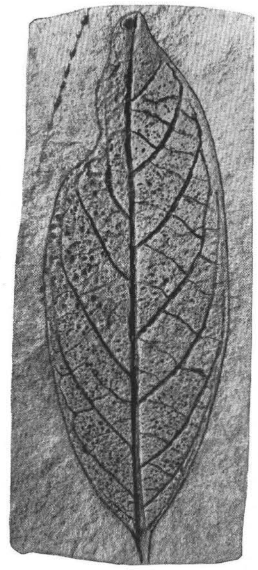
PLATE XXII



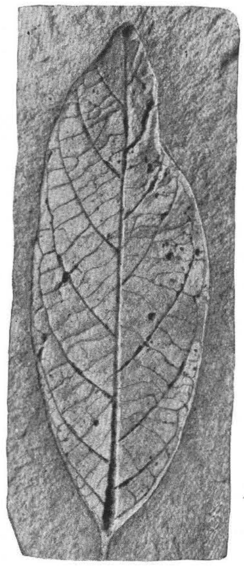
FOSSILS OF LATAH FORMATION



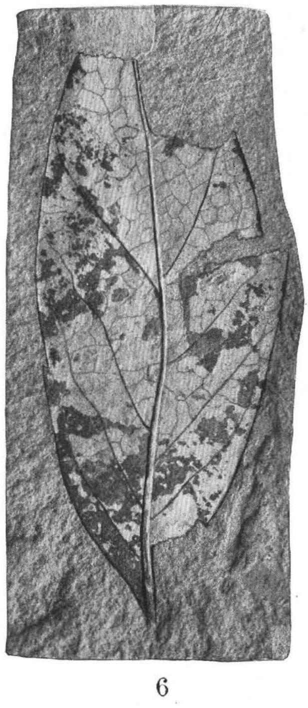
1



4



5



6

2

3

FOSSILS OF LATAH FORMATION

PLATE XXIII

Page

FIGURES 1, 2. *Laurus princeps* Heer. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36971. (Fig. 2 counterpart of fig. 1, given to show nervation.) 41

3. *Laurus princeps* Heer. Well at Mica, southeast of Spokane, Wash. U. S. Nat. Mus. No. 36972 41

4–6. *Laurus similis* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. Nos. 36973, 36974. (Fig. 5 counterpart of fig. 4, given to show details of nervation.) 41

PLATE XXIV

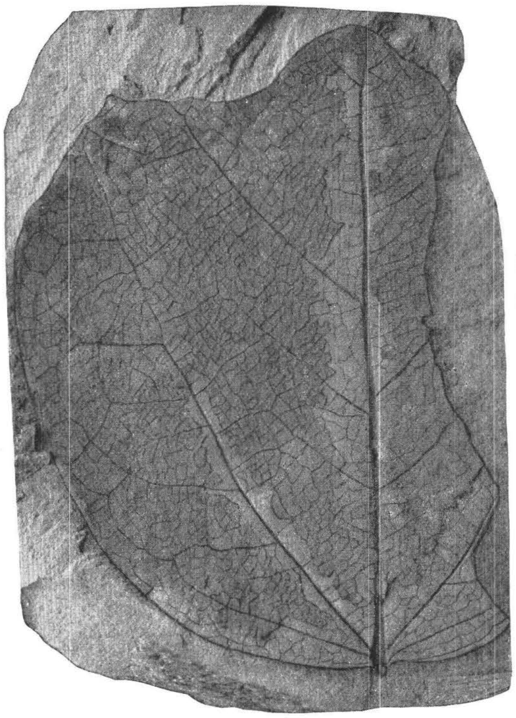
	Page
FIGURE 1. *Laurus grandis* Lesquereux. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36975	41
2. *Laurus similis* Knowlton. Cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash. Specimen in University of California, No. $\frac{3940}{22959}$	41
3. *Magnolia dayana* Cockerell. Spokane, Wash. U. S. Nat. Mus. No. 36976	41
4. *Prunus rustii* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36977	43
5. *Prunus rustii* Knowlton. Cut No. 2, Chicago, Milwaukee & St. Paul Railway, Spokane, Wash. U. S. Nat. Mus. No. 36978	43
6. *Hydrangea bendirei* (Ward) Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36979	42

PLATE XXV

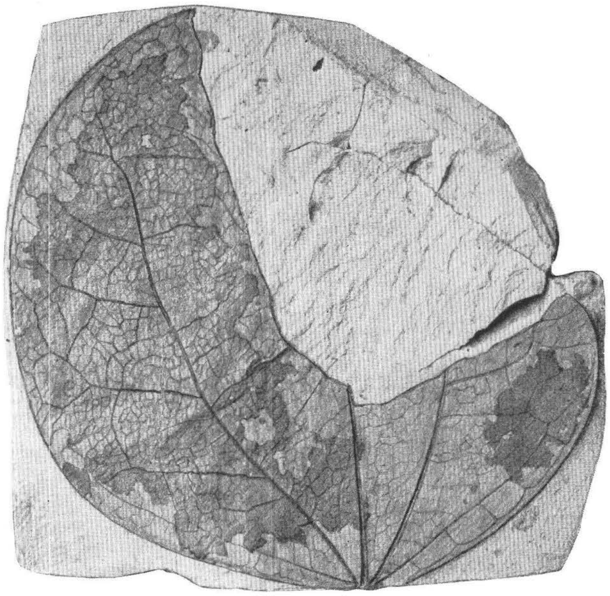
	Page
Ficus? washingtonensis Knowlton. Spokane, Wash. U. S. Nat. Mus. No. 369 80	40

PLATE XXVI

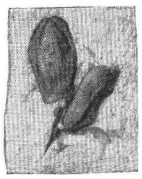
		Page
FIGURES 1–3.	*Ficus? washingtonensis* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. Nos. 36981, 36982, 36983	40
4.	*Carpites menthoides* Knowlton. Spokane, Wash. Specimen in University of California, No. $\frac{3940}{22855}$	49
5.	*Equisetum*, underground stems. Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36984	24
6.	*Carpites spokanensis* Knowlton. Cut No. 2, Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash. U. S. Nat. Mus. No. 36985	49
7.	*Carpites polygonoides* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36986	49
8.	*Phyllites sophoroides* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36987	48



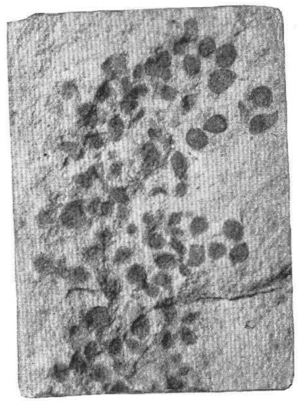
1



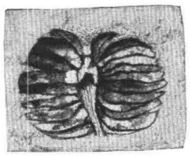
2



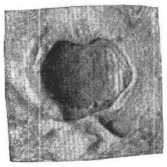
6



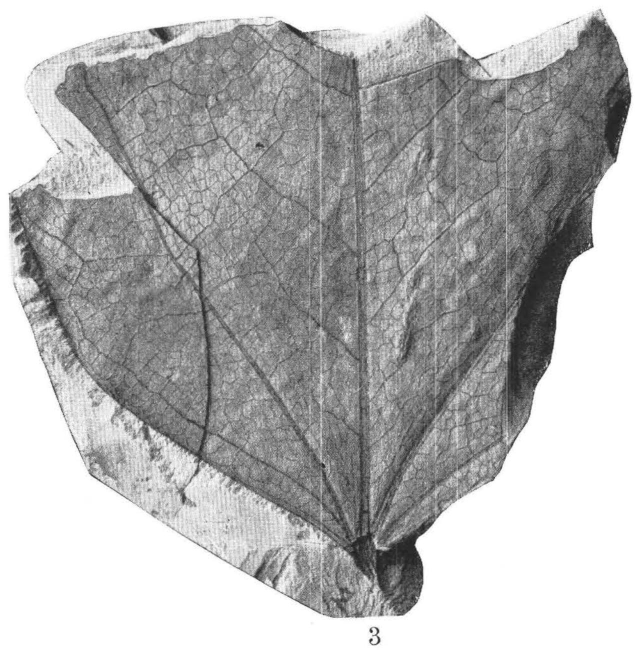
7



4



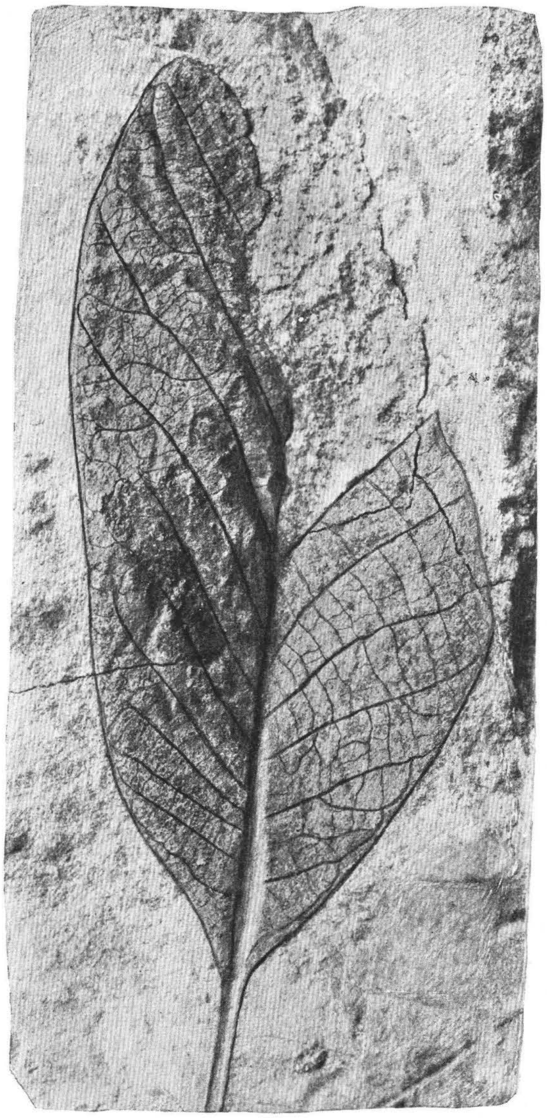
5



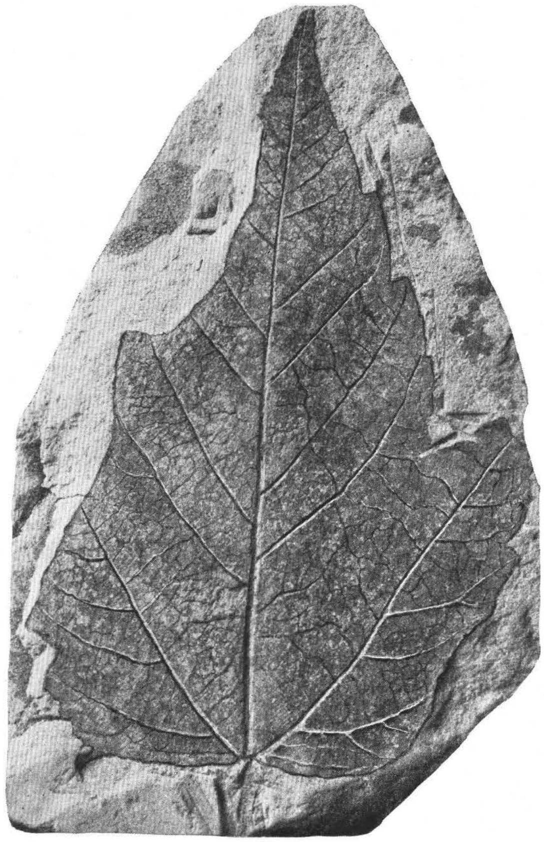
3

8

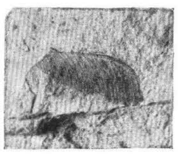
FOSSILS OF LATAH FORMATION



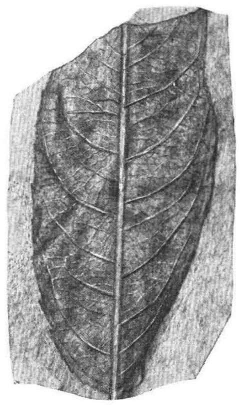
1



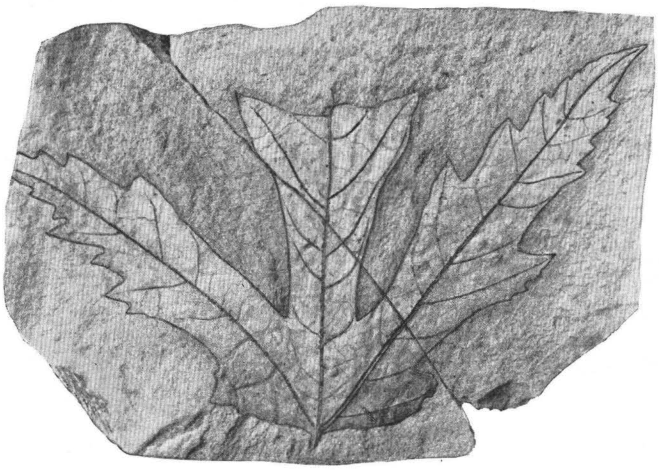
3



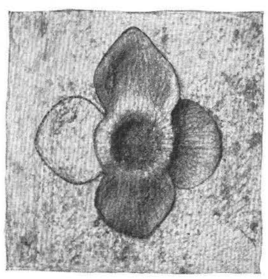
4



5



2



6

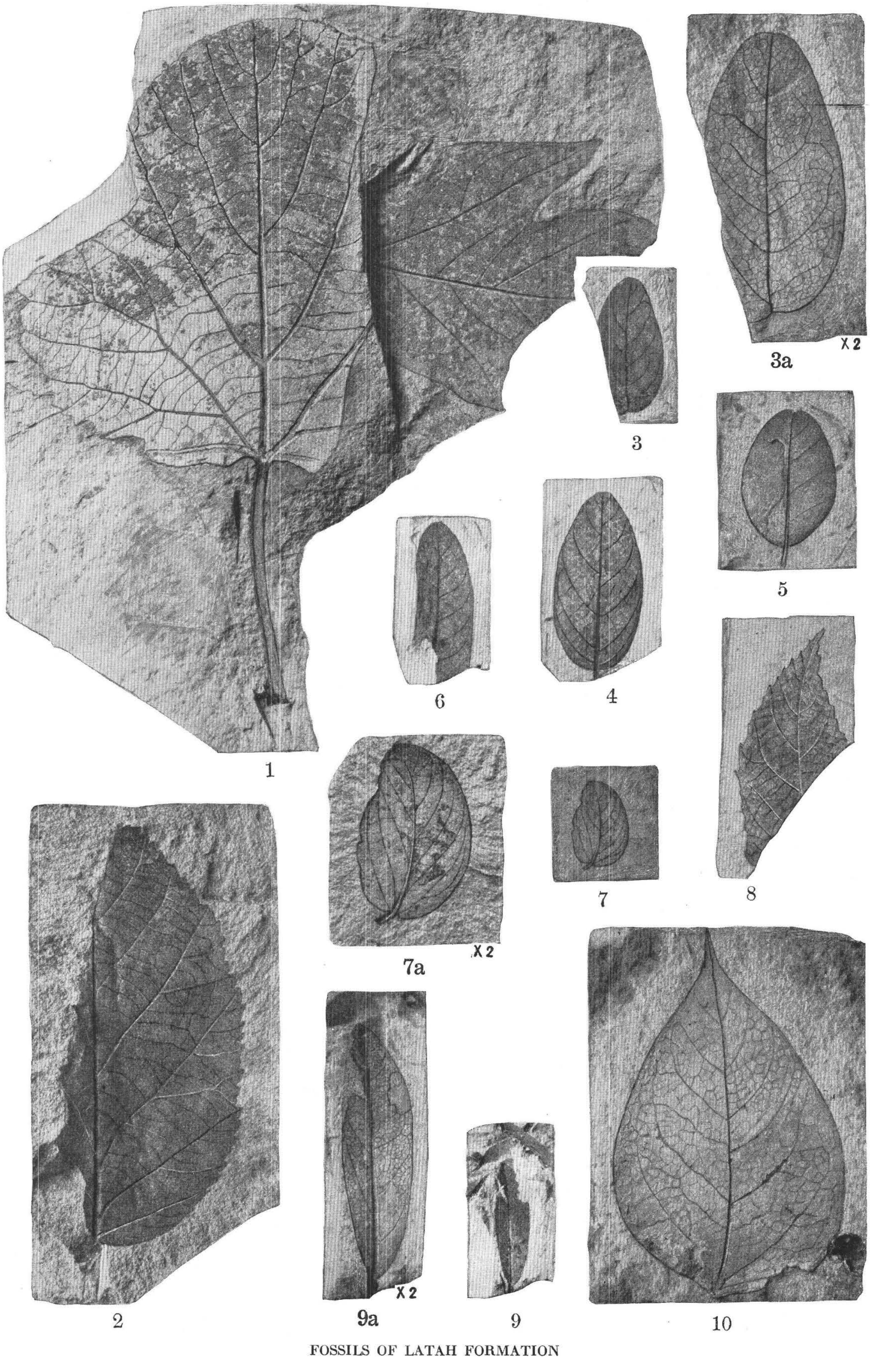
FOSSILS OF LATAH FORMATION

PLATE XXVII

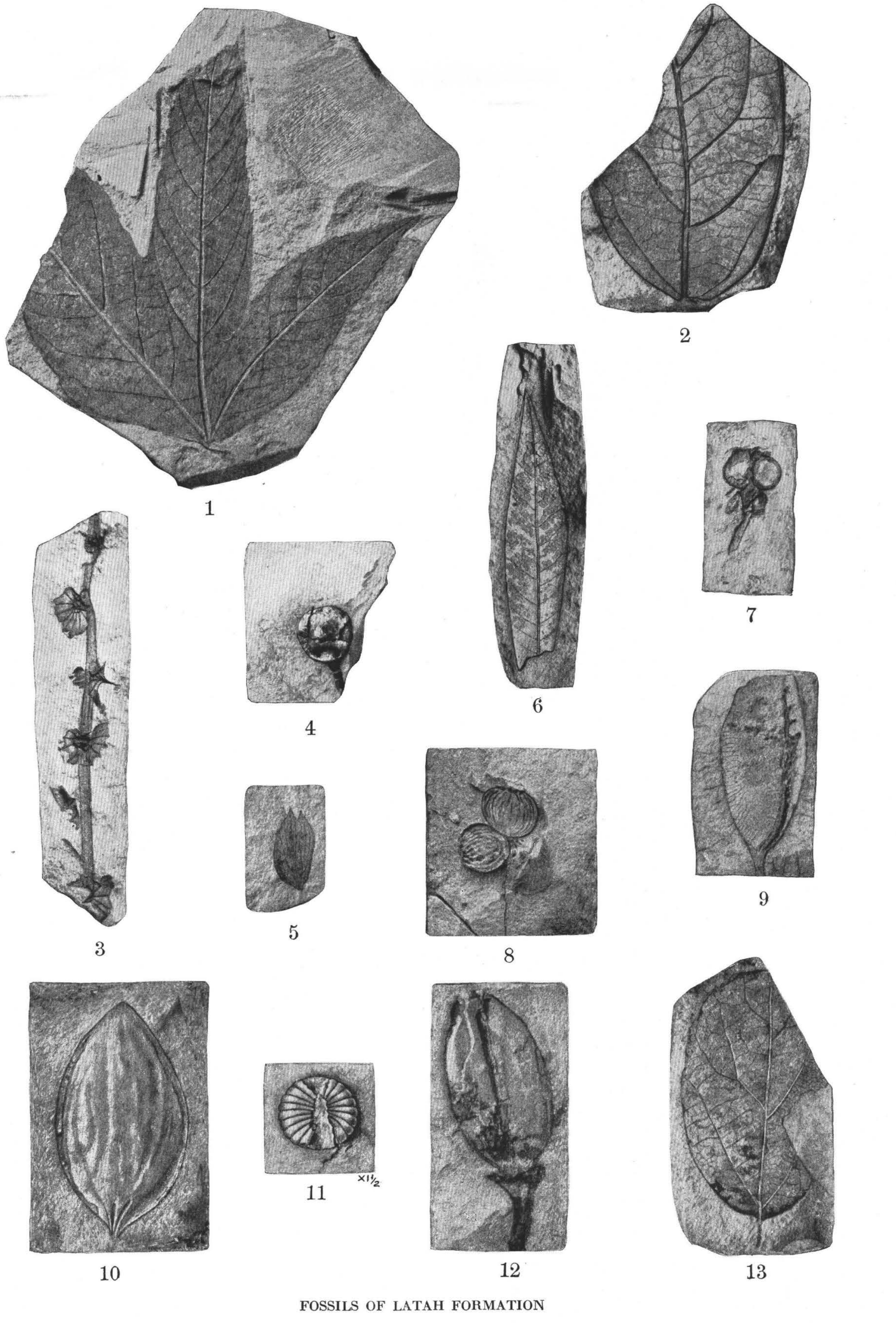
		Page
FIGURE 1.	*Magnolia* sp. Twelfth Avenue and Thor Street, Spokane, Wash. U. S. Nat. Mus. No. 36988	41
2.	*Acer chaneyi* Knowlton. Spokane, Wash. Type in University of California, No. $\frac{3940}{22962}$	45
3.	*Acer bendirei* Lesquereux. Well at Mica, southeast of Spokane, Wash. U. S. Nat. Mus. No. 36989	45
4.	*Acer minor* Knowlton. Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36990	45
5.	*Rhus typhinoides* Lesquereux. Clay pit 2 miles south of Vera, Wash. U. S. Nat. Mus. No. 36991	45
6.	*Diospyros andersonae* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36992	46

PLATE XXVIII

		Page
FIGURE 1.	*Acer merriami* Knowlton. Well at Mica, southeast of Spokane, Wash. U. S. Nat. Mus. No. 36993	45
2.	*Celastrus fernquisti* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36994	44
3–5.	*Sophora alexanderi* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. Nos. 36995, 36996, 36997. (Fig. 3a is same as fig. 3, × 2.)	43
6.	*Sophora spokanensis* Knowlton. Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36998	44
7, 7a.	*Robinia?* sp. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36999. (Fig. 7a is same as fig. 7, × 2.)	44
8.	*Phyllites relatus* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 37000	48
9, 9a.	*Vaccinium salicoides* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 37001	46
10.	*Meibomites lucens* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 37002	44



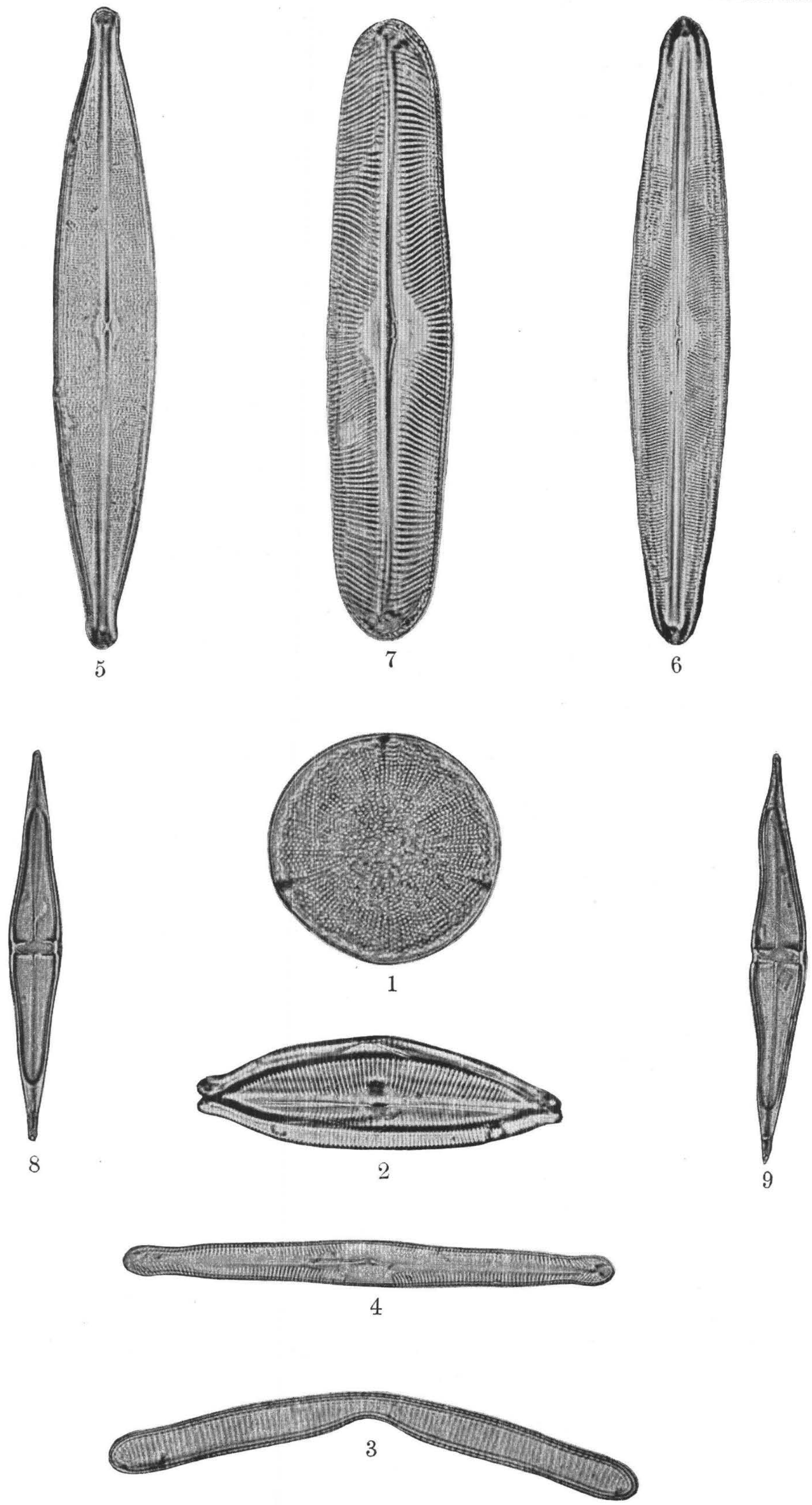
FOSSILS OF LATAH FORMATION



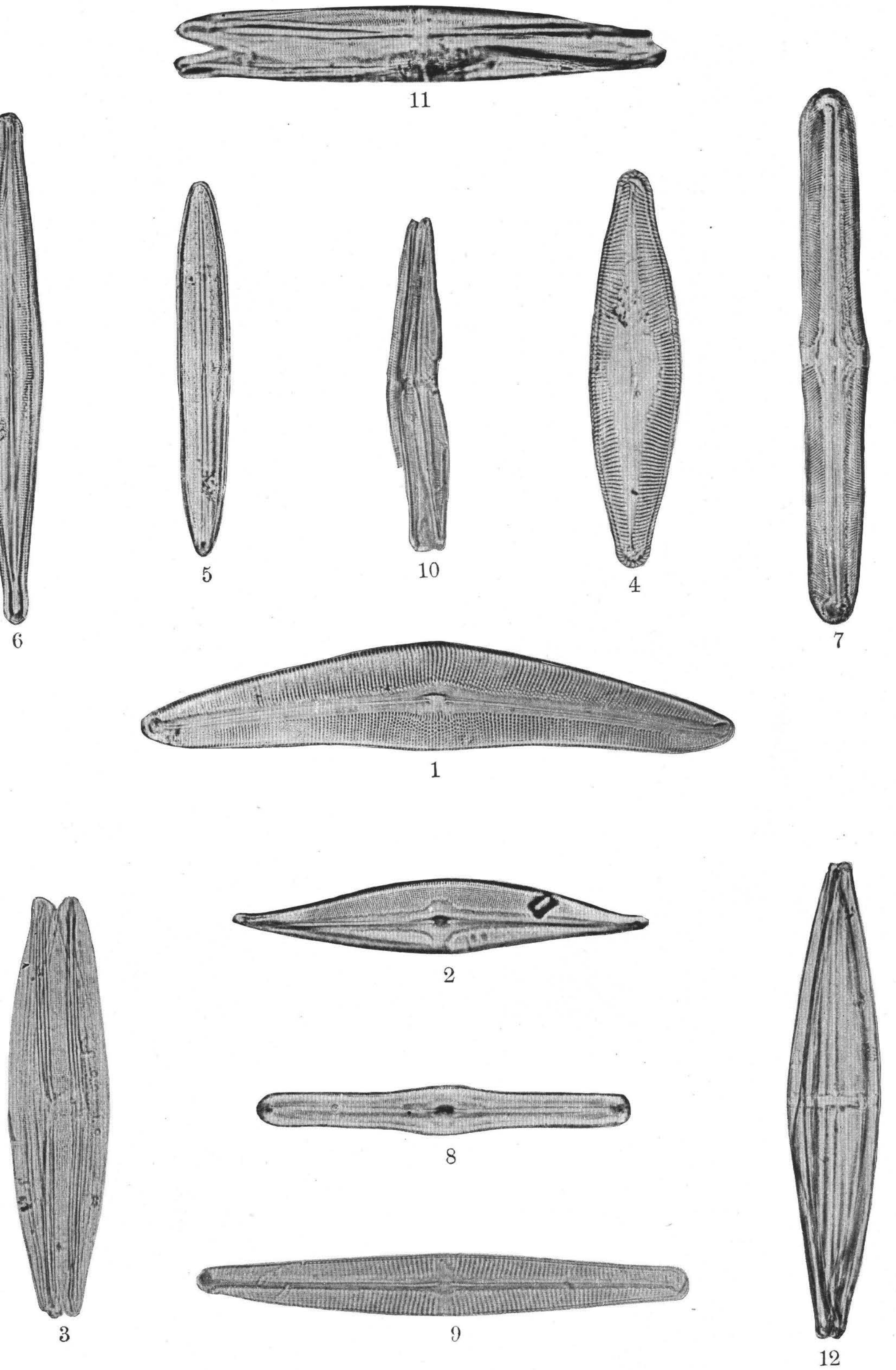
FOSSILS OF LATAH FORMATION

PLATE XXIX

PLATE XXX



FOSSILS OF LATAH FORMATION



FOSSILS OF LATAH FORMATION

PLATE XXXI

		Page
FIGURE 1.	*Cymbella partita* Mann, n. sp., × 500	53
2.	*Cymbella sagittarius* Mann, n. sp., × 570	53
3.	*Frustulia rhomboides* (Ehrenberg) De Toni, twins, face view, × 860.	
4.	*Navicula contendens* Mann, n. sp., × 800	53
5.	*Navicula iridis* Ehrenberg, delicate dwarf variety, × 650.	
6.	*Navicula pauper* Mann, n. sp., × 540	54
7.	*Navicula pontifica* Mann, n. sp., × 450	54
8.	*Navicula protrudens* Mann, n. sp., × 710	54
9.	*Navicula substauroneis* Mann, n. sp., × 680	54
10.	Same, twins, girdle view, × 440.	
11.	*Stauroneis anceps* Ehrenberg, twins, girdle view, × 620.	
12.	*Stauroneis phoenicenteron* Ehrenberg, twins, face view, × 410.	

FOSSIL PROBOSCIDEA AND EDENTATA OF THE SAN PEDRO VALLEY, ARIZONA

By James Williams Gidley

INTRODUCTION

A preliminary report on the fossil vertebrates of the San Pedro Valley, Ariz., collected by Kirk Bryan and me in the winter of 1920 and 1921 was published in 1922.[1] This report includes a brief statement regarding the geology of the locality and a preliminary list of fossil vertebrates obtained by the expedition of 1921, with descriptions of the rodents and rabbits. Two additional papers on this interesting fauna have also appeared, one on the turtles by C. W. Gilmore[2] and one on the birds by Alexander Wetmore.[3] The present contribution deals with the proboscideans and edentates and gives a somewhat fuller discussion of the geology of the fossil-bearing beds.

GEOLOGY AND FAUNAL ASPECT OF THE SAN PEDRO VALLEY DEPOSITS

As stated in the preliminary report, most of the material collected came from two localities, which seem to be slightly different in age. One of these is on the west side of the valley near the town of Benson; the other is on the east side of the valley in the vicinity of the Curtis Flats, about 12 miles from the Benson locality Stratigraphically and structurally the beds of these two localities seem to be equivalent in age. The faunas of the two localities, however, seem to belong to slightly different time periods. In fact, the collection obtained from one locality differs so widely from that of the other—there being no species in common—that the deposits evidently represent two distinct time periods. These faunas, however, contain several genera in common, and the species are so nearly related as to indicate that the time interval between the two periods represented was probably not great. Further study of the material seems to sustain my first impression that the fossil-bearing beds near Benson are slightly older than the Blanco formation of Texas, and that the beds near Curtis Flats are somewhat younger. It must be admitted, however, that this opinion is not based on any very tangible or direct evidence, and more comparisons should be made, especially with the Blanco faunas. In its favor is the fact that the beds of the Benson locality contain remains of a mastodon with enamel-banded tusks, *Neohipparion*, *Protohippus* (or *Pliohippus*), *Merycodus*, and other forms of distinctly Miocene or Pliocene affinities, whereas the *Stegomastodon* and *Glyptotherium* of the Curtis Flats locality seem closely related to but slightly more progressive than species of these genera found in the Blanco formation. The presence of true *Equus*, which was found in the Curtis Flats locality and in one place south of the Benson locality, will doubtless be considered by some as evidence of Pleistocene age. However, the fact must be taken into account that the occurrence of this genus in the Pleistocene is confined to the earlier stages, and also that even there it is represented by several well-defined species of diversified character, ranging in size from a Shetland pony to a draft horse. It must therefore be admitted that the genus *Equus*, as at present defined, must have had a very considerable period of development prior to its first general appearance in the regions of our best-known collecting fields of Pleistocene age, both in America and in Europe. If this is true it would not be surprising, and in fact it might be expected, that occasional advance guards of the later general invasion of this genus reached America long before the beginning of Pleistocene time. In my opinion this is just what happened in the San Pedro Valley and other localities of the extreme West.

Even more puzzling than the question of exact correlation of the San Pedro Valley faunas with those of other areas is the apparent disagreement, to which I have already referred, of the geologic and faunistic evidence relative to the respective time phases of the two adjacent localities here under discussion. A detailed study of the deposits themselves, however, seems to offer a solution.

As surveyed and reported by Bryan,[4] the deformed valley fill, which includes the fossil-bearing beds, occurs in a strip lying on both sides of San Pedro River from the Mexican boundary north to Gila River. This material consists of cemented gravel and conglomerate, which generally border the mountains, and of finer material, which in general occupies the middle and lower parts of the valley. The formation as a whole is the result of deposition in an arid intermontane valley. It has been deformed and faulted by renewed uplift of the bordering mountains, but in general the finer-grained beds in the center of the valley were little affected by these movements and for the most part are undisturbed and horizontal. However, several partial cycles of erosion ensued after the period of uplift, and large parts of the formation were removed, the amounts eroded varying from place to place.

[1] U. S. Geol. Survey Prof. Paper 131, pp. 119-131, 1922.
[2] U. S. Nat. Mus. Proc., vol. 61, pp. 1-8, pls. 1-5, 1922.
[3] U. S. Nat. Mus. Proc., vol. 64, art. 5, pp. 1-18, figs. 1-9, 1924.

[4] Bryan, Kirk, and Smith, G. E. P., Geology and water resources of San Pedro Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper — (in preparation).

The two localities lie on opposite sides of San Pedro River about 12 miles apart but at similar altitudes. The beds at both are horizontal and, except for evidence of minor faulting in those near Benson, apparently undisturbed. A thickness of about 250 feet is exposed in this part of the valley, but the total thickness of the formation is much greater, as shown by the logs of wells in the vicinity. The fossil-bearing layers are somewhat above the middle of the eroded section and are hence near the top of the formation. The stratified beds of these localities consist principally of red clays, sands, and soft limestones that were evidently laid down in salt lakes of small extent in the central part of the Pliocene basin.

The bones occur for the most part in relatively small patches or layers of greenish tuffaceous clay, which, according to Bryan, interfinger on one side with arkosic gravel and conglomerate typical of deposition on alluvial slopes and on the other with the lake beds. This position seems to confirm Bryan's view that these bone-bearing patches of greenish clay represent the marginal and fresh-water springs that are characteristic of the borders of salt lakes in such basins. The localities thus probably constituted the chief watering places for the animals of the region, and here, naturally, occur their fossil remains.

That these areas were once boggy water holes is supported by the condition and arrangement of the bones they contain. For example, the skull of one of the mastodons was found completely covered by the undisturbed original matrix and lying in a horizontal position resting on the lower jaws, but the top portion of the skull was crushed and eroded and the tips of the tusks reaching to the same level were broken. This damage had evidently been done while the skull yet lay partly buried in wet mud. Also the left fore leg of this animal was found in nearly normal position relative to the skull, but with the toes directed downward, reaching a level in the clay 2 feet below it. This position indicates that the animal came to his death by being hopelessly bogged. The position and arrangement of the other bones as found suggest that they had been moved about by being more or less trampled and disturbed by contemporary animals who were so fortunate as to escape being engulfed in the soft and sticky mud. A foot of each of the other two mastodons collected was found in a like position, giving additional evidence of boggy conditions. The carapace of *Glyptotherium* showed evidence of trampling. The top had been caved in before being completely covered and may have been thus crushed by the foot of a *Stegomastodon arizonae* while lying partly buried.

If, then, we accept Bryan's view regarding the conditions of deposition, it is plainly evident that the accumulation of material in the central portion of the San Pedro basin must have taken place comparatively slowly, as these lakes, to become thus saline, must have required long periods of desiccation. The few inches to 2 feet of soft limestone that marks their former existence must therefore represent a very considerable length of time, at least a few thousand years. The springs that were marginal to the lakes must have had similar periods of existence.

Under these conditions it is quite possible that, although the general process of sedimentation in the San Pedro basin was continuous, the marginal springs of the two localities may have belonged to lakes of slightly different levels. Thus the time interval between the active existence of the watering places on the west side of the salt lakes at the Benson locality and those on the east side of the lakes at Curtis Flats may well have been long.

During this interval the faunas changed, but it does not necessarily follow that this change was greatly affected by evolution in this locality, for, although considered long as measured in years, the interval was probably in a geologic sense relatively short, and it may well be that the entire change was accomplished by migration. In fact, a comparison of the faunas seems to confirm this supposition. For example, the species of mastodon found at the Curtis Flats can not be a descendant of the one found at the Benson locality, as it belongs to a very different phylum. The Equidae, the Carnivora, the Rodentia, and, in fact, the species in general found in one locality present nothing indicating their derivation from their relatives of the other locality. In other words, though many of the species of the Curtis Flats locality are closely related to species found in the Benson locality, the former are not descendant forms of the latter.

DESCRIPTIONS OF SPECIES

Order PROBOSCIDEA

Two distinct phyla of mastodons, referable to two or possibly three new species, appear in the collections from the San Pedro Valley. One phylum, represented by a single specimen found in the locality just south of Benson, belongs to the group of mastodons with tusks possessing a band of enamel and of the nearly straight, twisted variety; the other is represented by three specimens from the Curtis Flats locality.

Genus ANANCUS Aymard

Genotype.—Anancus avernensis (Crozet and Jobert).

This genus is based on an Old World species which is characterized by long, nearly straight, twisted, and enamel-banded tusks and by the fact that the third molars have five and one-half cross lophs. The Benson specimen seems to belong to this genus, but the third molars have only four cross lophs.

Anancus bensonensis Gidley, n. sp.

Plate XXXII

Type.—The greater part of the basal portion of a skull from the posterior nareal opening forward, including the orbital and zygomatic region, and portions of the squamosal and paraoccipital of one side. The cheek teeth, except right m^2, and part of the alveolar sockets of the tusks are also preserved. Part of this specimen was obtained through exchange from the University of Arizona, and parts were collected by Bryan and Gidley.

Type locality.—About 2½ miles south of Benson, Ariz., in sec. 22, T. 17 S., R. 20 E.

Horizon.—Middle or upper Pliocene.

Diagnosis.—Molars brachyodont, semibunodont; m^2 trilophodont, m^3 tetralophodont with small heel; main cusps of upper molars wearing to trefoil pattern in both rows, but this pattern appears earlier and is better defined in the cusps of the inner side; lophs relatively low and set at right angles to the long axis of the tooth crown; valleys shallow and almost completely blocked medially by the accessory buttresses of the inner row of cusps; rostrum long, very broad, and but little bent down on the plane of the palate, being nearly continuous in direction with it, and seemingly correlated with the possession of nearly straight tusks; palate rather broad and but slightly arched.

The following are additional features which may be considered more or less distinctive. The posterior nares is relatively small and is oblong-elliptical in cross section, and its anterior wall slopes forward and upward from the nareal notch at an angle of about 45°. The glenoid surface is relatively broad antero-posteriorly, and its borders are not sharply defined. This surface is characteristically proboscidean in being slightly concave transversely and convex antero-posteriorly. In the Benson mastodon, as in *Mastodon americanum*, there is a transverse sulcus formed behind the glenoid surface by a broad transverse expansion of the paraoccipital. This sulcus, however, is much shallower and narrower than in the Pleistocene species, because the paraoccipital is more closely appressed to the glenoid portion of the squamosal. This feature denotes a shortening of the skull in this region and seems to affect the position of the external auditory meatus, which is situated directly above or slightly forward from the middle of the glenoid surface. In the Indiana mastodon this opening is situated distinctly farther backward and is also placed higher above the glenoid surface. The zygomatic process of the squamosal is relatively very short, and its anterior articular border rises abruptly at a much greater angle than in *M. americanum.* The orbit is relatively high above the tooth row and is placed well forward, its anterior border being directly above the anterior border of m^2. The infraorbital foramen is large and is placed high upon the face as compared with this foramen in *M. americanum.* Also the maxillary border of the orbit rises abruptly at the point where it meets the jugal, indicating that there still remained in this species a well-defined inferior postorbital process.

Another striking peculiarity of the Benson species is the fact that in connection with the broad and remarkably long rostrum the anterior extremities of the premaxillaries are greatly thickened. A similar thickening of the premaxillaries may be observed in old individuals of the present-day African elephant.

In the present confused state of our knowledge of the diversified species of mastodons, it is most difficult to define accurately the limits of the several genera that have been proposed. In consequence it has long been recognized that a thorough revision of the group of Proboscidea would be most desirable. I have not attempted such a revision in connection with my present study, for this important and much needed work is already nearing completion under the able direction and personal studies of Prof. Henry Fairfield Osborn, and the present reference of the species here described to *Anancus* may therefore be considered only provisional. In this connection it should also be noted that the type of *A. bensonensis* seems to combine characters of species usually regarded as belonging to quite distinct genera. In *Anancus avernensis* of Europe, in the South American species "*Mastodon andium,*" and in "*Tetralophodon shepardi edensis,*" a California species recently described by Childs Frick, the tusks are apparently of the long, nearly straight type, are set rather widely apart, are but slightly divergent in the skull, and apparently have a downward turn as they emerge from the alveoli; but whether or not in *Anancus bensonensis,* they were twisted and possessed a band of enamel, as in the three species just mentioned, is not known.[5] From the form and length of the rostrum it seems reasonable to infer that the Benson species was possessed of lower jaws of the elongate and probably tusked type, but this inference can not be verified until lower jaws have been found.

[5] Since writing the above description I have again visited the San Pedro Valley, where I made a second collection of fossil vertebrates, this time for the American Museum of Natural History. Among other specimens obtained is a mutilated tusk from the Benson locality. This tusk seems with little question to belong to the species of mastodon here described. If so, it entirely corroborates the statement made above, for it is sufficiently well preserved to show that it was about 4 feet long and about 4 inches in diameter and that it is of the nearly straight, twisted variety and possesses a wide band of enamel extending along nearly its entire length. This tusk was found at approximately the same level as that from which the type specimen was taken and only a few hundred feet distant from it. Its form agrees exactly with that of the alveolus in the type of *Anancus bensonensis.* In this connection it may be noted that in the same bed at a somewhat lower level, only a few feet away from the tusk just described, was another tusk of quite different character giving positive evidence of a second type of mastodon belonging to the Benson phases. This one, however, was too badly shattered and displaced to be preserved, but it showed by the natural mold left in the matrix which had surrounded it that it was of the short, thick, much curved, and rapidly tapering variety; also, there was no evidence of an enamel band. Two juvenile tusks from these beds, now in the American Museum of Natural History collection, give further evidence of two types of mastodons in the Benson locality. One of these is about 10 inches long and about 1½ inches in diameter and possessses a well-developed enamel band; the other is somewhat larger, is more curved, and has no enamel band.

A specimen from the California locality in the American Museum of Natural History (No. 24047) has been referred to "*Tetralophodon*" *edensis*. This specimen has the anterior portion of the rostrum preserved, with portions of nearly straight, twisted, and enamel-banded tusks in place. It has thickened premaxillaries, as in *Anancus bensonensis*, but this thickening is markedly less pronounced, and the rostrum is relatively shorter.

Comparative measurements indicate that *Anancus bensonensis* is larger than either the South American or the California species and is further distinguished from the latter by important differences, especially in the last upper molar. M^3 of the Benson species has the same number of lophs, but it is relatively longer crowned, and the transverse crests are parallel instead of outwardly diverging, as in the California species. The lophs are also less elevated, and the valleys are more open; also, there is a well-developed cingulum on the inner border of the crown, and the fourth transverse loph, instead of being small, as in "*Tetralophodon*" *edensis*, is nearly as broad and prominent as the third loph. The molars of *T. edensis* are described as having no cingula.

Measurements of type skull of Anancus bensonensis

[Catalog No. 10538, U. S. National Museum]

	Millimeters
Length of m^2	125.0
Width of m^2 (measured at middle loph)	88.5
Length of m^3	191.0
Width of m^3 (measured at second loph)	99.0
Diameter of tusk (estimated from alveolus)	130.0
Basal length of skull from postnareal notch forward	815.0
Greatest width of palate (between posterior lophs of second molars)	120.0
Narrowest point of palate (between posterior lophs of last molar)	76.0
Distance from m^2 to anterior end premaxillary	460.0
Extension of maxillary anterior to m^2	390.0
Width of skull at orbit (computed)	750.0
Width of rostrum at narrowest point (estimated)	550.0
Width of premaxillaries at exit of tusks (estimated)	640.0
Width of premaxillaries between alveolar borders of tusks	355.0
Vertical diameter of premaxillaries at anterior extremity	125.0
Vertical diameter of orbit	180.0

Genus STEGOMASTODON Pohlig

The genus *Stegomastodon* was proposed by H. Pohlig in 1912[6] and was based on the species *Mastodon mirificus* Leidy.

The generic position of the species described below, founded on materials from the Curtis Flats locality, can be assumed with much more confidence than that of the Benson species just described. Its general characteristics, which include a short, narrow, spoutlike symphysis of the lower jaw and the reduction of the dental series in each jaw to a single six or seven lobed bunodont molar in the older adult stage, mark it rather definitely as belonging to the group typified by *Stegomastodon mirificus* (Leidy). Although only the characters of the lower jaw are known from the type, a nearly complete skull and lower jaws from the Blanco formation of Texas, now in the American Museum of Natural History, has been referred by Osborn to this group, and a comparison of this specimen seems to confirm the generic reference of the Curtis Flats specimens, although their specific rank appears to be quite distinct.

Stegomastodon arizonae Gidley, n. sp.

Plates XXXIII–XXXIX

Type.—Portion of skeleton of a young adult male, including the base portion of the skull with tusks and cheek teeth in place; the lower jaws; both fore limbs (one with nearly complete foot); parts of both hind limbs; the pelvis; and several of the more characteristic vertebrae and ribs (catalog No. 10707, U. S. National Museum).

Referred material.—(1) Portions of a skeleton of a moderately old male, including the basal portion of the skull with teeth and tusks in place; the lower jaws; a fore limb and foot lacking only the proximal end of the humerus and the greater portion of the scapular blade; a few ribs and vertebrae; and the sacrum with parts of the pelvis (catalog No. 10556, U. S. National Museum). Found at about the same level as the type specimen, and about 100 yards distant. (2) A complete hind foot and distal end of tibia associated with a lower jaw lacking teeth (catalog No. 10917, U. S. National Museum). Found about 50 feet from No. 10556 and at the same level.

Type locality.—Curtis Flats, about 14 miles southeast of Benson, Ariz., in sec. 25, T. 18 S., R. 21 E.

Diagnosis.—Skull short; rostrum short and bent sharply downward on the plane of the palate; lower jaws with short symphysis, spoutlike chin and no tusks; a single tooth in each jaw in old individuals, as in *Stegomastodon mirificus* (Leidy); tusks without enamel, large, stout, much curved, and widely spreading so that at the point of exit from the skull they diverge at right angles to each other; second molars when present, tetralophodont, or nearly so; third molars sextalophodont or septalophodont, with heel; lophs when unworn relatively high, with summits of main cusps closely approached, leaving the shallow longitudinal median valley nearly closed; principal cusps of the last lower molar not arranged in straight lines antero-posteriorly, as in most species of mastodons, but curving outward posteriorly, giving to the tooth crown a twisted appearance.

The cusps of these molars, above and below, arise one above the other in the jaw, so that the anterior

[6] Soc. belge géologie Bull., vol. 26, p. 193, 1912.

lobes, appearing much earlier, are deeply worn before the more posterior ones come into use. These last two are progressive characters which parallel or are rather tending toward the condition of tooth replacement found in the true elephants and which mark this species of mastodon as having advanced, at least in this respect, much beyond the better-known later survivor of this great group of Proboscidea, *Mastodon americanum*. The tendency toward elephantlike development of the last molars of *Stegomastodon arizonae* is an important difference to be noted in comparing it with *S. mirificus*, the latter being a less progressive species. In *S. mirificus* the summits of the lophs are more nearly on the same plane and are more evenly worn by use, as in *Mastodon americanum*. This progressive feature is also strongly marked in certain species of Old World mastodons and is likewise present, but to a much less degree, in certain other American species, as *Megabelodon lulli* Osborn and *Tetrabelodon campester* Cope.

Comparative measurements of Stegomastodon and Mastodon, in millimeters

Teeth, skulls, and jaws

	Stegomastodon arizonae		*Mastodon americanum*, aged adult (catalog No. 8204)	*Stegomastodon mirificus*, type, aged adult (catalog No. 209)
	Type, young adult (catalog No. 10707)	Referred, aged adult (catalog No. 10556)		
Length of m^2	95		119	
Width of m^2	86		90	
Length of m^3	212	260	185	
Width of m^3 at second loph	97	87	95	
Length of m_2	110		120	
Width of m_2	92		90	
Length of m_3	230	258	180	210
Width of m_3 at second loph	98	77	102	76
Diameter of tusk (greatest)	160	192	205	
Diameter of tusk (least) at same point	128	162	205	
Basal length of skull from condylar notch	820		1, 045	
Length of m^2 to anterior end premaxillaries	300+		405	
Length of palatal notch to end premaxillaries	580		760	
Width of skull at orbits	605		745	
Width at exit of tusks	600	500	185	
Width at narrowest point of rostrum	340	400	525	
Width of maxillaries at posterior end of tooth rows	230	260	300	
Width of palate at narrowest point	49	85	107	
Width of palate at widest point	70	98	185	
Length of lower jaw, condyle to symphysis	740	800	965	
Length from angle to point of symphysis	662	670	750	
Length from cheek-tooth row to point of symphysis	200	210	250	220
Depth of jaw at condyle	345	410	515	
Depth of jaw at coronoid process	300	335	445	
Depth of jaw at anterior end of m^3	150	200	201	
Antero-posterior diameter of symphysis	140	121	155	73
Vertical diameter of symphysis	75	121	125	70

Skeleton

	Stegomastodon arizonae		*Mastodon americanum* (catalog No. 8204)
	Type (catalog No. 10707)	Referred (catalog No. 10556)	
Length of cervical series	[a] 1, 450		480
Length of dorsal series	1, 445		1, 650
Length of lumbar series	250		360
Length of sacral series	[b] 350	[c] 285	[b] 363
Total length of presacral vertebral column	[a] 2, 035		2, 490
Length of centrum of first dorsal	45		70
Length of centrum of second dorsal	55		80
Length of centrum of twentieth dorsal			80
Length of centrum of first lumbar	75		80
Height of anterior dorsal spines, first	225		405
Height of anterior dorsal spines, second	385		550
Height of anterior dorsal spines, third	420		550
Height of anterior dorsal spines, fourth	425		520
Length of scapula, glenoid cavity to top	765		920
Distance from top to posterior angle of blade	780		910
Distance from spine to posterior angle of blade	512		510
Distance from spine to anterior angle of blade	150		150
Length of metacromion	285	315	365
Antero-posterior diameter at constriction below spine	230	235	230

[a] Restored. [b] 4 vertebrae. [c] 3 vertebrae.

Comparative measurements of Stegomastodon and Mastodon, in millimeters—Continued

Skeleton—Continued

	Stegomastodon arizonae		*Mastodon americanum* (catalog No. 8204)
	Type (catalog No. 10707)	Referred (catalog No. 10556)	
Antero-posterior diameter at corocoid	245	185	270
Antero-posterior diameter of glenoid cavity	195	125	197
Transverse diameter of glenoid cavity	130	175	130
Height of spine	[d] 145	----------	180
Length of humerus, head to inner condyle	850	----------	905
Length of supinator ridge, external condyle to top of rugosity	285	325	395
Antero-posterior diameter of head	210	----------	235
Greatest diameter at proximal end	345	240	330
Transverse diameter of distal articular surface	201	705	210
Greatest length of ulna	720	----------	795
Length at sigmoid notch	660	555	655
Sigmoid notch to post extremity of olecranon	225	195	270
Transverse diameter at distal end	135	135	[a] 160
Length of radius	630	635	675
Greatest diameter at proximal end	110	140	125
Transverse diameter at distal end	148	175	130
Antero-posterior diameter at distal end	98	115	143
Total width of carpus	----------	255	[a] 283
Depth of carpus between radius and Mc III	----------	160	145
Length of Mc III	----------	130	145
Length of third digit including Mc III	----------	330	[a] 290
Greatest width of pelvis	1, 475	----------	1, 800
Greatest length of ilium	820	----------	1, 030
External point of ilium to acetabulum	440	----------	545
Width of sacral end of ilium at narrowest point	335	----------	240
Length of pubic symphysis	[b] 440	----------	545
Distance from acetabulum to end of ischium	345	----------	310
Transverse diameter of pelvic opening	415	----------	505
Transverse diameter of obdurator foramen	100	----------	140
Antero-posterior diameter of obdurator foramen	195	----------	255
Length of femur, head to internal condyle	1, 010	----------	1, 050
Diameter of head	167	----------	175
Diameter through head and trochanter	335	----------	310
Transverse diameter at distal end	[b] 215	----------	245
Antero-posterior diameter at distal end	240	----------	235
Greatest diameter at middle of shaft	145	----------	155
Least diameter at middle of shaft	65	----------	95
Length of tibia	645	----------	660
Transverse diameter of proximal end	230	----------	250
Transverse diameter of distal end	160	----------	170
Total length of hind limb as mounted	1, 890	----------	2, 150
Total length of fore limb as mounted	2, 485	----------	2, 670

[a] Cast from the "Warren" mastodon skeleton mounted in the American Museum of Natural History, New York City, substituted in the National Museum mount.
[b] Estimated.
[d] About.

Additional skull and skeleton characters.—*Stegomastodon arizonae* is typically proboscidean throughout in skull and skeleton characters, as might be expected, and in many respects, therefore, it resembles *Mastodon americanum.*[7] Certain important modifications, however, may be noted, which clearly distinguish it from this type of mastodon and also from the *Gomphotherium* group in so far as the osteologic characters of that group are known.

The *skull,* above a plane passing through the base of the orbits and the upper border of the condyles, is wanting, but the portion preserved, which includes the jugal of the left side and carries the cheek teeth and both tusks in place, indicates clearly that it is not of the elongate type, like that of *Mastodon americanum* and *Gomphotherium,* but is much more brachyocephalic than either. In addition the tusks are relatively short, much curved, and widely divergent; the rostrum is short, broad, and bent sharply downward immediately in front of the cheek teeth, much as in the elephants; and the palatal region in the type skull is very narrow and little or not at all arched.

The *lower jaws* are moderately long but have a short, deep symphysis with narrow, spoutlike chin and no tusks.

The *scapula* is much like that of *M. americanum,* being readily distinguished from the *Elephas* type by the relatively broader proportions of its posterior blade. The metacromion is a long, well-developed process, as in *M. americanum,* extending backward from the lower half of the spine to form a wide V-shaped valley with the likewise well-developed acromion. Compared with the Indiana specimen this valley is shallower and the metacromion is less downwardly directed, being nearly at right angles with the scapular spine.

[7] For convenience, most of the comparisons are made with the nearly complete skeleton of the Indiana mastodon, a male *M. americanum,* now on exhibition in the National Museum (catalog No. 8204), which is essentially like the "Warren" mastodon now mounted in the American Museum of Natural History, well known through published descriptions.

The *humerus* is of about the same robust proportions as that of the Indiana mastodon but differs from it in some important respects. The deltoid ridge seems to be relatively thinner and higher, is less rugose, and is extended distally considerably farther along the shaft. Likewise the supinator ridge, although relatively shorter and less salient in its prominent rugose distal portion, extends its proximally diminishing portion much farther up the shaft. Thus the ends of these two prominent ridges overlap each other for a much greater distance than in the Indiana mastodon and in consequence form a conspicuous longitudinal external sulcus, which in the Indiana specimen is not present or but weakly defined. Also the internal condylar ridge in the Arizona species is more prominent and more backwardly extended. Compared with that of *M. andium*, the humerus is relatively robust, and it agrees rather closely in general proportions with that of *Gomphotherium angustidens*. Of seemingly less importance is the fact that the relative length of the rugose portion of the supinator ridge in *S. arizonae* is but little less than one-third the total length of the humerus; in *M. americanum* it is definitely more than one-third this length; in *G. angustidens* it is shortest, being definitely less than one-third; and in *M. andium* it is longest, being nearly one-half the total length of the humerus.

The *ulna* differs from that of the Indiana specimen in that the olecranon process is relatively very short. This seems to be characteristic also of the true elephants. The *radius* is much like that of *M. americanum* and seems to differ only in that the head is more expanded antero-internally and narrows up to a greater degree externally, thus making it more definitely triangular in cross section.

The *fore foot* is in general much like that of *M. americanum* but is somewhat more slender in proportions. The carpus and metacarpal III are about equal in length. In *M. americanum* the carpus exceeds the length of metacarpal III, and the phalanges are relatively longer.

The *pelvis* differs from that of *M. americanum* in having the anterior border of the ilium more convexly curved in outline, viewed from behind, and the upper or sacral portion is more expanded anteroposteriorly. The pubic symphysis is long, as in *M. americanum*, but its posterior region seems to be not so robust nor so conspicuously produced backward and downward as in that species. The uncertainty of this statement is due to the fact that this portion of the pelvis is somewhat crushed and damaged. Crushing also prevents an accurate and detailed comparison of the *femur* and *tibia*, but these bones have about the same general proportions and modifications as those of *M. americanum*.

The left astragalus is all that was found to represent the *hind feet* of the type specimen, but there is in the collection a nearly complete hind foot of another specimen (No. 10917) associated with a portion of a lower jaw showing the alveolus for a single cheek tooth, which seems to warrant its reference to this species. This foot was found with the bones all articulated, nearly in their normal position but so firmly cemented together that they can not be separated for detailed study. The general characteristics, however, can be clearly made out. The tarsal elements are relatively thick compared with those of the Indiana mastodon, hence the tarsus as a whole is longer and narrower than that of *M. americanum*. The toes, on the contrary, are relatively short, and the lateral pair, D I and D V, have the phalanges much reduced, those on D I being apparently represented by a single shapeless nodule of bone. The terminal phalanges of the other toes are also apparently wanting.

Comparative measurements of the hind feet of Stegomastodon arizonae and Mastodon americanum,[a] *in millimeters*

	Stegomastodon arizonae (catalog No. 10917)	*Mastodon americanum* (catalog No. 8204)
Transverse width of calcaneum	165	175
Antero-posterior diameter at distal end	135	130
Transverse width of astragalus (tibial face)	130	130
Thickness at anterior face	50	40
Transverse width of navicular	150	155
Thickness at anterior face	46	29
Transverse width of external cuneiform	71	90
Thickness at anterior face	52	35
Transverse width of metatarsal III (proximal end)	74	75
Length of metatarsal III	100	110
Total length of digit III	145	205
Vertical thickness of tarsus at digit III	165	143
Total width of tarsus	315	350

[a] Part of this foot of the Indiana mastodon is restored by using casts of the bones of the "Warren" mastodon now on exhibition in the American Museum of Natural History, New York City.

Although the *axial skeleton* of the type is by no means complete, its general characters are rather clearly indicated by several typical vertebrae and ribs. Portions of the first four dorsal vertebrae, including the spines, the last two dorsals, the three lumbars, the sacrum, and the anterior two caudals, are preserved. Many of the ribs are represented by pieces of various completeness. These taken together are sufficient to form a fairly accurate basis for restoration of the body portion of the skeleton, which seems to correspond in general with that of the Indiana mastodon, although certain differences of detail may be noted. In the Indiana specimen the spine of the first dorsal approaches in height those of the second and third, which are equal and the highest of the series. In the Arizona specimen the fourth dorsal spine is the highest, the second is next, the third a little shorter, and the first still shorter, being relatively much shorter than the corresponding one of the Indiana mastodon.

Specimen No. 10556, provisionally referred to *Stegomastodon arizonae* (p. 86), in so far as the corresponding portions preserved will permit comparison, seems to present the principal characteristics distinctive of the species. It differs from the type, however, in certain important details. These may be briefly stated as follows: (1) It represents a larger individual (see table of comparative measurements, p. 87); (2) the cheek teeth are reduced to a single one (m^3) in each jaw; (3) m^3, both upper and lower, is relatively and actually narrower than that of the type, and, although much worn, indicates clearly that the homologous lophs are relatively less elevated and the valleys correspondingly less open; (4) the tusks are notably larger and less cylindrical, being subquadrate in cross section; (5) the symphysis of the lower jaw is deeper; and (6) the palate is deeply arched and about twice the width of that of the type skull.

Such differences as these, if found at all constant where abundant material is available, would unquestionably be considered as indicating two distinct species. In the present instance, however, only two specimens can be compared, and I am therefore inclined to consider most of these differences, at least, as due to individual variations and age changes, both of which are generally recognized as being considerable in most species of proboscideans. Although both specimens are adult, the paratype was evidently a much older individual, and to this fact may be attributed, for example, its generally larger proportions and the more advanced stage of development of the cheek teeth. It does not, however, account for the smaller size and different proportions of the teeth, nor would it seem to explain entirely the great difference in width and form of the palate, although this modification would doubtless be very considerably affected by it. The type is a young adult, yet it had reached the stage in which the limb bones and most of the vertebrae had entirely closed the sutures of their epiphyses. Although the second molars are worn nearly to the roots and were about to be shed, the hinder molars had not yet fully emerged from the jaw bone, and only the anterior loph of each is worn to any degree. In the referred specimen the anterior molars have entirely disappeared and the last molars had emerged to their full height in the jaws, yet in these only the two anterior lophs are deeply worn, the third is moderately worn, and the fourth is just beginning to show signs of wear. As both specimens seem to be of the same sex (male), sex variation need not be considered in this comparison.

General features of the skeleton as mounted.—In addition to the characteristics pointed out in the above detailed description, a few features worthy of note are presented in the general skeletal structure of *Stegomastodon arizonae* as restored and mounted. The general proportions of the skeleton are in part conjectural. However, the length of the back, computed from the few characteristic vertebrae preserved, and the definitely known features of the skull indicate rather clearly that *S. arizonae* was relatively higher and shorter than *Mastodon americanum;* both the pelvis and the skull are more elephantlike in general form, but the tusks are much more divergent than is usual in any proboscidean.

Two characteristic features relative to the fore limbs in the Proboscidea were very clearly brought out in the mounting of both this specimen and the skeleton of the Indiana mastodon. One concerns the proper location of the shoulder joint; the other relates to the normal position of the elbow joint. In seeking to determine where to place the scapulohumeral joint, it was observed that the second rib to a greater degree and the third to a less degree were bowed inward just above mid-section, and that the first rib was also depressed on its posterior border in the same region. Thus there is formed a broad, shallow depression in the anterior-superior rib structure, which obviously can be for no other purpose than to accommodate or give room for the limited play of the heavy shoulder joint. The skeletons of living species of elephants examined show a like structure; hence it may be assumed to be characteristic of the Proboscidea in general. To follow up this idea, several skeletons of the larger, heavier ungulates were examined, and most of them were found to show a similar but usually less distinct depressed area. Its position, however, is not the same in the ungulates as in the Proboscidea, being lower and more anterior, so that its center comes between the first and second ribs and near their distal ends. This difference in position seems to be correlated with the greater angulation of the shoulder and elbow joints in the ungulates.

In determining the normal position of the elbow joint, it was found in articulating the bones of the fore leg that by placing the fore foot in a normal position—that is, rather well under the body—the elbow joint was brought around to a position in which its transverse axis was directed at a very oblique angle to the transverse axis of the body, and thus the anterior planes of these joints face obliquely inward, instead of nearly directly forward, as in most ungulates. This also seems to be a distinctly proboscidean feature and is apparently a purely mechanical adaptation necessitated by the great weight and bulk of the creature. An observer watching an elephant walk will note that the fore foot, as it leaves the ground and is started forward for the next step, is well to the outside of the perpendicular longitudinal plane of the body; hence, in order to take the weight of the body again on coming to the ground, it is carried forward and obliquely inward across this plane. The opposite fore leg, swinging inward and forward in its turn, gives the peculiar side to side swaying motion of the shoulders as the animal moves forward. Thus the fore legs of proboscideans do not move directly forward in a straight walk but swing in an inward-directed oblique plane; hence the obliquity of the elbow joint when placed in a normal position.

Order EDENTATA

Suborder GLYPTODONTIA

The existence of glyptodonts in the United States was first made known by Cope, who in 1888 described one-half of a single scute of the carapace as the type of a new species, *Glyptodon petaliferus*.[8] In the next several years other fragments of glyptodonts were discovered and described, but nothing of importance came to light until 1903, when an American Museum expedition discovered in the Blanco (Pliocene) formation of western Texas a partial skeleton consisting of a nearly complete carapace, a pelvis, a sacrum, a caudal series, and a complete tail armature. This material was described by Osborn, who made it the basis of a new genus and species, *Glyptotherium texanum*.[9] Next followed Brown's description of some good specimens from Mexico, discovered in part by himself and in part by other collectors at a much earlier date. On this combined material he founded the new genus *Brachyostracon*.[10] Brown states that the earlier collections mentioned, consisting of two nearly complete carapaces of glyptodonts, were discovered near Tequixquiac. One of these is preserved in the Mexican National Museum of Natural History, the other in the National School of Engineers in Mexico City. The former was described in 1874 by Señores J. N. Cuatáparo and Santiago Ramírez, who gave it the name *Glyptodon mexicanus*. This material was mentioned by Dr. Marino Barcena in 1882, by Cope in 1884, and again by Dr. Manuel M. Villada in 1903 (see Brown's article for references). Villada gave a faulty drawing of the carapace in the Natural History Museum. The descriptions given by these authors were very inadequate; hence our first real knowledge of the Mexican glyptodonts came through Brown's contribution, just cited. The next important contribution is that of Hay,[11] who in 1917 described a specimen (catalog No. 6071, U. S. N. M.) from supposed Pleistocene deposits in Wolf County, Tex. This specimen includes several characteristic parts of the carapace and skeleton. Hay referred it to Cope's species *Glyptodon petaliferus*, and compared it in detail with the South American species *Glyptodon asper* Burmeister, to which he considered it generically related.

Thus up to the present time only four valid species, representing three genera of glyptodonts, have been reported from North American localities. Two of these species came from Mexico, the other two from the United States. Now, a fifth species, represented by good material, has been discovered in the Curtis Flats locality of the San Pedro Valley and is here described. This species seems to belong to the genus *Glyptotherium* as defined by Osborn.

Genus GLYPTOTHERIUM Osborn

Genotype.—*Glyptotherium texanum* Osborn, from the Blanco (Pliocene) formation of western Texas.

This genus is characterized by a relatively elongate carapace, simple tail structure, and relatively primitive carapace plates, which are arranged in more or less regular lateral rows extending over the back and of which the central areas are distinctly larger than the peripheral ones in all parts of the carapace. Another characteristic of this genus, given by Brown for *Glyptotherium texanum* and verified in a specimen of *G. arizonae* from the Curtis Flats locality collected in 1924 for the American Museum of Natural History, is that the pubes are reduced to thin rods of bone.

Glyptotherium arizonae Gidley, n. sp.

Plates XL–XLIV

Type.—Part of a skeleton, including the lower jaws; complete limbs and feet of the right side; a section of the back bone; portions of the carapace, including the nearly complete border of the right side; and various detached scutes of the carapace and tail rings (catalog No. 10536, U. S. National Museum).

Paratypes.—Nearly complete tail piece, including vertebrae and bony rings, and hinder lower border portions of the carapace of both sides (catalog No. 10537, U. S. National Museum); the greater part of the carapace with a few teeth and foot bones associated (catalog No. 10336).

Type locality.—About 3 miles east of the Curtis ranch, in sec. 25, T. 18 S., R. 21 E., Cochise County, Ariz., about 10 feet above and 100 feet distant from locality of the type of *Stegomastodon arizonae*.

Horizon.—Upper Pliocene deposits.

Diagnosis.—Size large, length of carapace about 1,700 millimeters (5 feet 8 inches) measured over curve of back, total length of animal about 2,285 millimeters (7 feet 7 inches); carapace elongate, with a small area of imbricated and more or less movable scutes bordering its anterior lateral margins; plates in all parts of the carapace, with central areas definitely larger than those of the periphery; carapace plates with depressed centers except those of the first, second, and parts of the third and fourth marginal rows; tail comprising twelve vertebrae and ten chevrons; tail armature with eight movable rings and a terminal cone composed of three closely sutured rings; tail armature and postero-lateral carapace plates moderately ornate.

---

[8] Am. Naturalist, vol. 22, p. 345, 1888.

[9] Osborn, H. F., Am. Mus. Nat. Hist. Bull., vol. 19, pp. 491–494, 1903.

[10] Brown, Barnum, Am. Mus. Nat. Hist. Bull., vol. 31, pp. 167–177, pls. 13–18, 1912.

[11] Hay, O. P., U. S. Nat. Mus. Proc., vol. 51, pp. 107–116, pls. 3–5, 1917.

Skull not known. Lower jaws deep, with massive, spoutlike symphysis, lower border nearly semicircular in outline, and ascending ramus relatively broad and directed well forward; cheek teeth all three-lobed, but the anterior two are not completely molariform, and the third from the front is more elongate than those posterior to it. Hind feet short and wide, with five subequal digits; fore feet short, with digit I vestigial or wanting, digits II and III subequal, constituting a stout, conspicuous pair, and digits IV and V much reduced.

Detailed description.—The *dentition* is represented by the complete lower series of the type and a few upper teeth associated with paratype No. 10336. It presents certain modifications which seem to be characteristic of the species. These teeth resemble

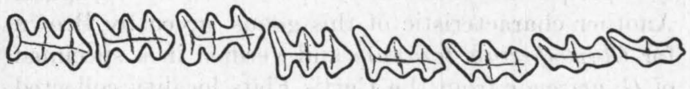


FIGURE 4.—*Glyptotherium arizonae* Gidley. Type. Lower cheek teeth of left side, one-half natural size.

in general form and proportions those of the South American glyptodonts, but differ in that the lobes of the molariform teeth are more oblique, their extremities are more angular, and the posterior face of the lower molars and anterior face of the upper are slightly indented by a shallow longitudinal sulcus. This gives a concave outline to the posterior lobes of the lower teeth and to the anterior lobes of the upper. In all other species of glyptodonts, so far as known, the posterior face of the lower cheek teeth is more or less convex. In general proportions the teeth of *G. arizonae* are like those of the South American genus *Glyptodon*, but they are more nearly like those of *Hoplophorus ornatus* (=*Lomaphorus ornatus*, fide Lydekker) as figured by Burmeister [12] in that they are relatively narrow and loosely spaced. In degree of specialization the anterior three teeth are rather intermediate between the more simple ones of *Hoplophorus* and the more completely molariform ones of *Glyptodon*.

Other features to be noted in the lower dentition of the Arizona species are the conspicuous prolongation of the posterior external angle, especially of the first four teeth, and the relatively great width of the anterior lobe in the hinder molars. Thus in the last four teeth of the series the anterior lobes exceed in width the middle lobes, and in all but the last one of the group the midlobe is exceeded in width by the posterior lobe also.

Of the elements of the *vertebral column* of this species anterior to the caudal region, only the dorsal tube is known. This is composed of ten fused vertebrae, as in *Panochthus*. According to Burmeister *Glyptodon* has eleven vertebrae included in this tube and *Hoplophorus* has twelve.

The *caudal vertebrae* are twelve in number and, like the tail armature, more nearly resemble those of *G. texanus* than they do any of the South American forms. They differ from those of the Texas species in that the processes of the anterior ones are relatively longer in the same proportion that the anterior rings are larger.

Both *scapulae* are well preserved in the type specimen and show some distinctive characteristics. As this element is not known in any other of the North American species, it can be compared only with South American forms. In general it resembles more nearly that of *Glyptodon* than that of *Panochthus* as figured by Burmeister, but it differs widely from both in its greater antero-posterior expansion and the relatively much greater extent of the rounded superior scapular border. The respective areas of the prescapular and postscapular fossae have about the same proportion to each other as in *Glyptodon*, but their form is quite different. In *Glyptodon* the prescapular fossa is ovoid in general outline, with the portion included in the suprascapular border only about one-half the extent of the prescapular border. In *Glyptotherium arizonae* this fossa is nearly triangular in outline, with the portion included in the suprascapular border nearly twice that of the prescapular border. The postscapular border is likewise proportionately much less extended than in *Glyptodon*.

The *humerus* of *G. arizonae* lacks the entepicondylar foramen, as in *Glyptodon*, but in proportion and other respects is more like that of *Hoplophorus*, which has this foramen well developed. Apart from the lack of the entepicondylar foramen, the humerus is distinguished from that of *Hoplophorus* in that both the deltoid and supinator ridges, though just as strongly developed, are less extended along the shaft. Also the bicipital groove seems to be narrower in the Arizona specimen, both supratrochlear fossae are relatively deep, and there is present in the type a well-defined supratrochlear foramen.

Like the humerus, the *radius* and *ulna* are relatively slender and more nearly resemble those of *Hoplophorus* than they do those of the other South American genera. The ulna especially is like that of *Hoplophorus*. In *Glyptodon* the shaft of the ulna is greatly shortened and deepened. The bones of the fore foot are peculiar only in that they are relatively very much shortened as compared with those of *Hoplophorus* and are nearly as robust as those of *Glyptodon*.

The *pelvis* of this species can not at present be described, although a complete one is preserved with a specimen recently collected from the Curtis Flats locality for the American Museum of Natural History. This is still in the matrix and will not be avail-

[12] Museo público de Buenos Aires Anales, vol. 2, pl. 19, figs. 2, 3, 1874.

able for description until it can be cleaned up. From my observations in the field, however, it may be stated that this pelvis has a much reduced pubis, as reported by Brown for *Glyptotherium texanum*.[13]

The *femur* of *G. arizonae* is very heavy and massive as compared with the humerus, but like the other limb bones, it is more slender in proportions than that of *Glyptodon*. It differs from the femora of all the South American forms, especially in the conformation of its distal end, which is definitely offset from the median line of the shaft toward the inner side, thus making a greater obliquity to the exterior border of the supinator ridge; it differs also in a definitely greater elevation of the great trochanter, which extends above the head of the femur. The femur of *G. petaliferus* described by Hay more closely resembles that of the Arizona species than it does that of *Glyptodon*. This is especially true of the form and character of the distal half of the shaft, which is quite as obliquely directed. The great trochanter, however, is much less elevated.

In the Arizona species the *hind foot* shows some important differences both in structure and in proportions from those of South American glyptodonts. It is much broader and more robust than those of *Panochthus* and *Hoplophorus* and is less robust than that of *Glyptodon*. In the less reduction of the lateral toes, the hind foot of *Glyptotherium arizonae* is like that of *Glyptodon* and differs from those of *Panochthus* and *Hoplophorus*. The form and arrangement of the tarsal elements, however, seem to differ widely from those of *Glyptodon* as compared with the figures given by Burmeister.[14] Among the most conspicuous differences to be noted are that the metatarsals in the Arizona species are proportionately long, the three cuneiforms, the cuboid, and the navicular are less widely expanded, the navicular is much less depressed in its middle anterior aspect, and the external and middle cuneiforms are entirely separated in front, owing mainly to the relatively greater elevation of the second metatarsal. Their borders come into direct contact in *Glyptodon*.

Although many of the modifications noted in the foregoing description of *Glyptotherium arizonae* may not be considered individually as distinctive, the combination of characters emphasizes the generic distinctness between the South American and North American glyptodonts.

It is not within the scope of this paper to review Hay's description of the glyptodont from northern Texas, which he referred to *Glyptodon petaliferus* Cope.[15] It may be stated, however, that although the teeth of this Texas form are more like those of *Glyptodon* than those of *Glyptotherium* in general character, such resemblances, with modifications as above designated in comparing the femora (seem to apply to all the skeletal elements so far as they are known. For this reason it seems probable that the species proposed by Cope and more adequately described on more complete material by Hay may prove to belong to a new genus. The great difference in geographic situation of the Texas locality and the type locality of *Glyptodon* adds to this probability. It is perhaps best, however, to retain this species where Cope and Hay have left it until more is known of the carapace and tail armature and the pelvic, sacral, caudal, and dorsal structure.

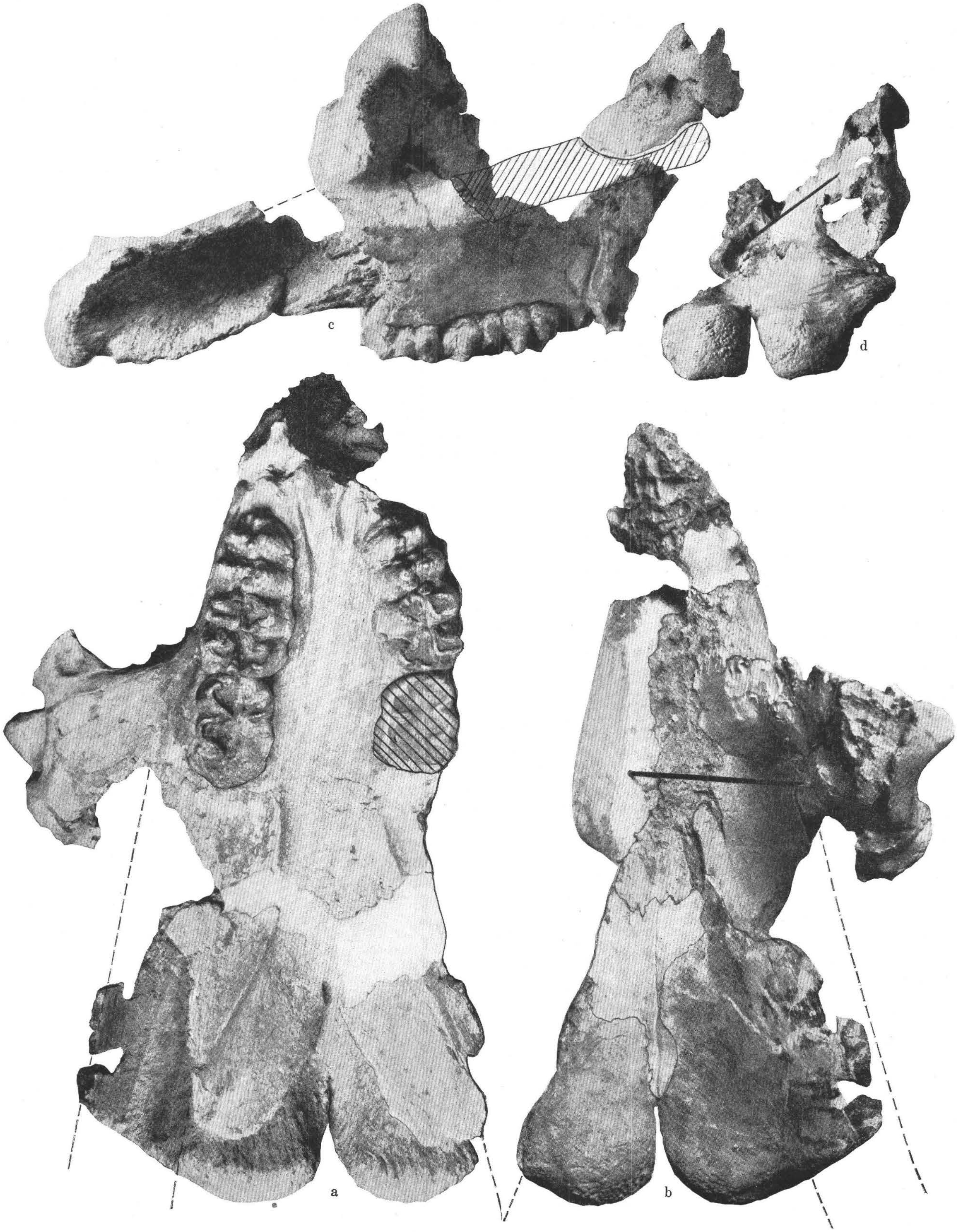
Measurements of Glyptotherium arizonae (type), in millimeters

Length of animal measured in straight line, including head and tail	2, 285
Length of carapace measured over curvature	1, 700
Greatest width of carapace measured over top	2, 120
Length of tail armature	895
Length of caudal vertebrae series	920
Length of proximal ring	83
Length of fourth ring	95
Length of eighth ring	105
Length of terminal cone	320
Vertical diameter of proximal ring	360
Vertical diameter of fourth ring	235
Vertical diameter of eighth ring	135
Vertical diameter of terminal cone	113
Transverse diameter of first caudal	368
Transverse diameter of fifth caudal	185
Transverse diameter of ninth caudal	85
Transverse diameter of twelfth caudal	28
Length of dorsal tube	465
Total length of lower jaw	323
Length of symphysis	145
Length of tooth row	202
Depth at sixth cheek tooth	93
Depth at condyle	245
Antero-posterior diameter of ascending ramus at tooth row	128
Greatest vertical depth of scapula	325
Greatest antero-posterior width	443
Antero-posterior diameter of articular face	83
Greatest transverse diameter of articular face	40
Length of acromion, measured on curve	120
Length of humerus, head to internal condyle	355
Greatest diameter of head	83
Transverse diameter of distal articular surface	72
Greatest diameter of proximal end	105
Greatest diameter at distal end	110
Narrowest transverse diameter of shaft	40
Length of radius between articular faces	170
Transverse diameter of proximal end	55
Transverse diameter of distal end	65
Greatest length of ulna	270
Length of olecranon	85
Length of shaft sigmoid notch to distal end	150
Transverse width of sigmoid surface	65
Transverse width of distal articular surface	60
Length of carpus betweeen radius and digit III	48
Length of digit III, including metacarpal	115
Length of terminal phalanx	70
Length of metacarpal III	22
Greatest width of carpus	100

[13] Brown, Barnum, Am. Mus. Nat. Hist. Bull., vol. 31, p. 175, 1912.
[14] Museo público de Buenos Aires Anales, vol. 2, pl. 36, 1874.
[15] Hay, O. P., U. S. Nat. Mus. Proc., vol. 51, pp. 107-116, pls. 3-5, 1916.

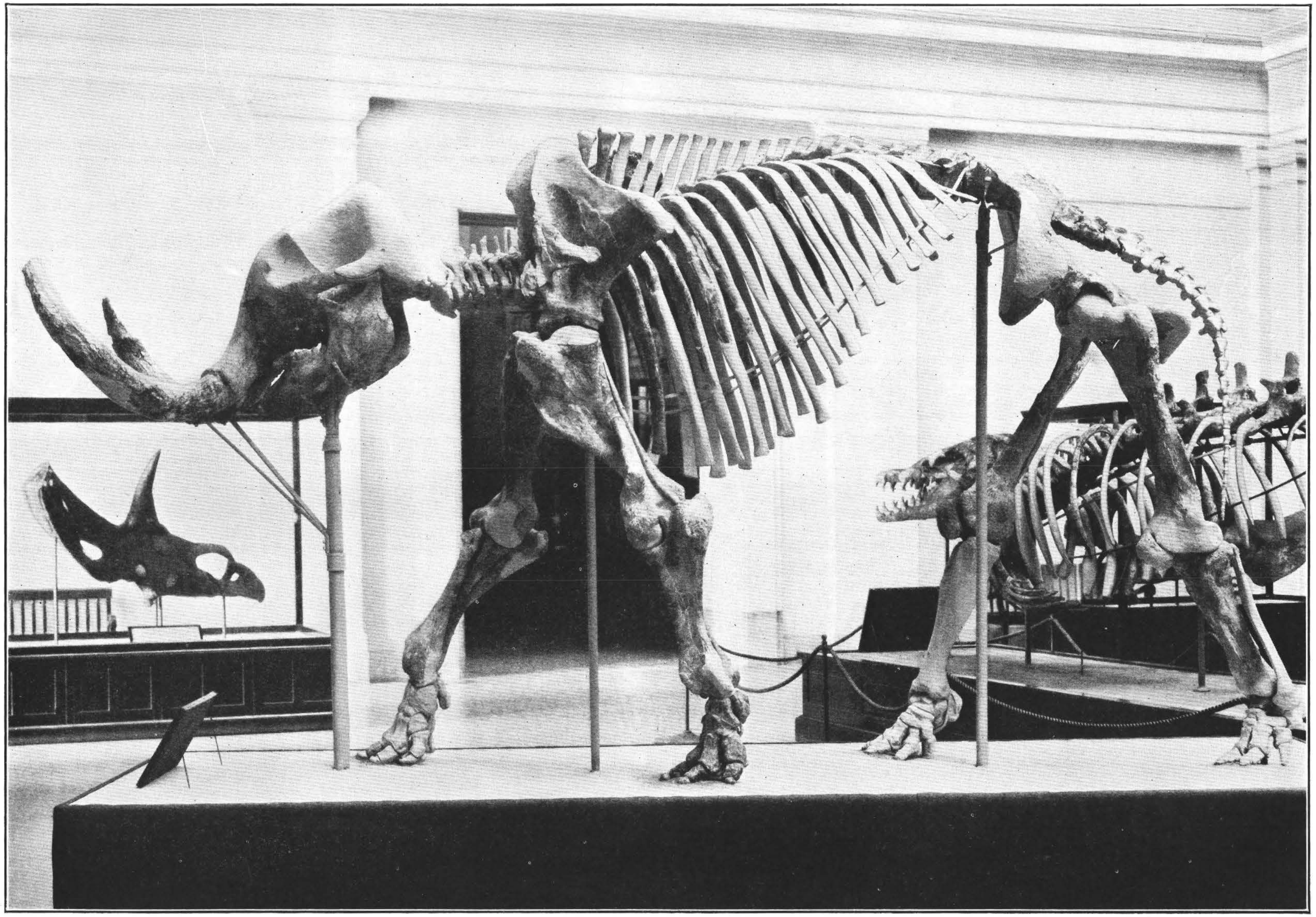
Length of femur head to internal condyle	456
Length of third trochanter to external condyle	496
Greatest diameter of head	92
Transverse diameter of distal articular face	130
Greatest width at proximal end	270
Length of supinator ridge	221
Transverse diameter of shaft at narrowest point	100
Diameter of shaft at upper end of supinator ridge	165
Length of tibia	220
Transverse diamater of tibia and fibula, proximal end	130
Transverse diameter of tibia and fibula, distal end	130
Length of tarsus between tibia and metatarsal III	40
Transverse width of same	105
Length of digit III, including metatarsal	115
Length of metatarsal III	33
Length of terminal phalanx	53

PLATES XXXII-XLIV



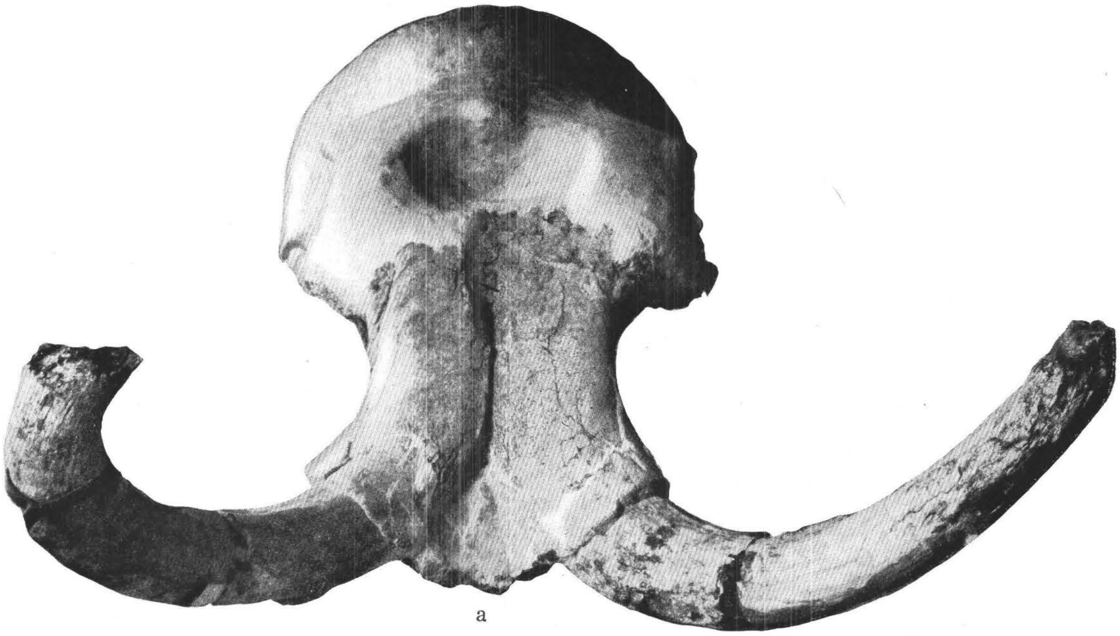
FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Portion of skull of *Anancus bensonensis* Gidley, n. sp., type (No. 10538, U. S. Nat. Mus.). a, Palate view; b, view from above; c, view from left side; d, anterior view. a, b, c, about one-sixth natural size; d, much reduced

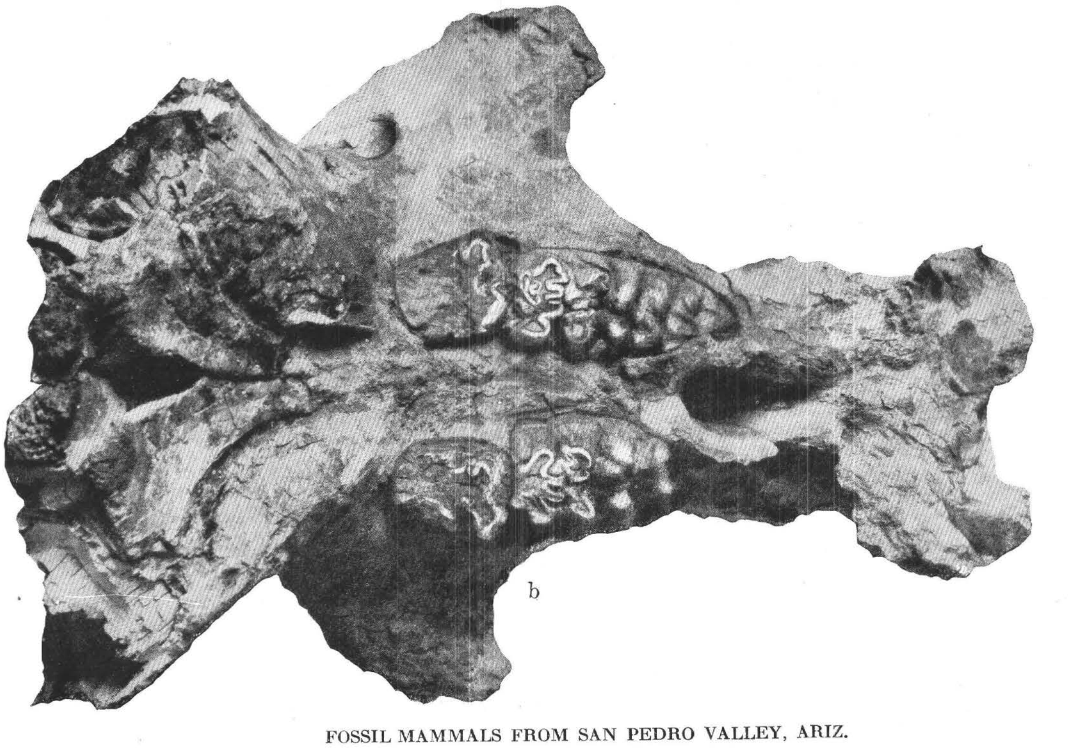


FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Skeleton of type of *Stegomastodon arizonae* Gidley, n. sp. (No. 10707, U. S. Nat. Mus.). A little less than one-twentieth natural size



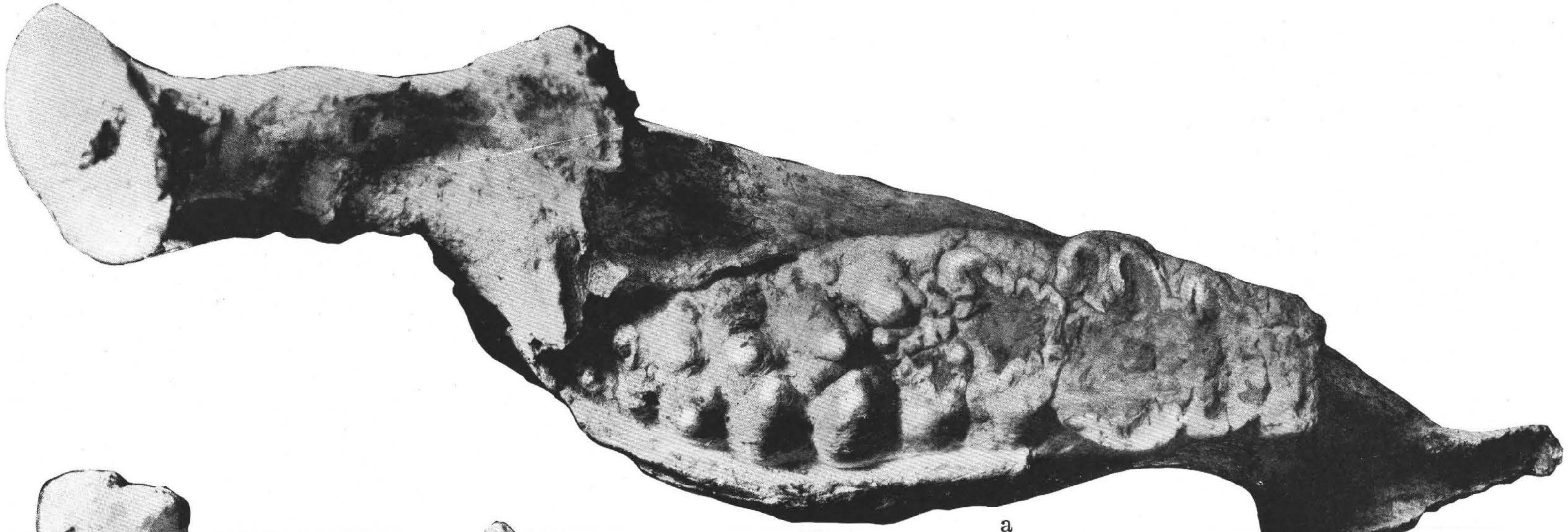
a



b

FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Skull of type of *Stegomastodon arizonae* Gidley, n. sp. (No. 10707, U. S. Nat. Mus.). About one-seventh natural size. a, Front view; b, palate view

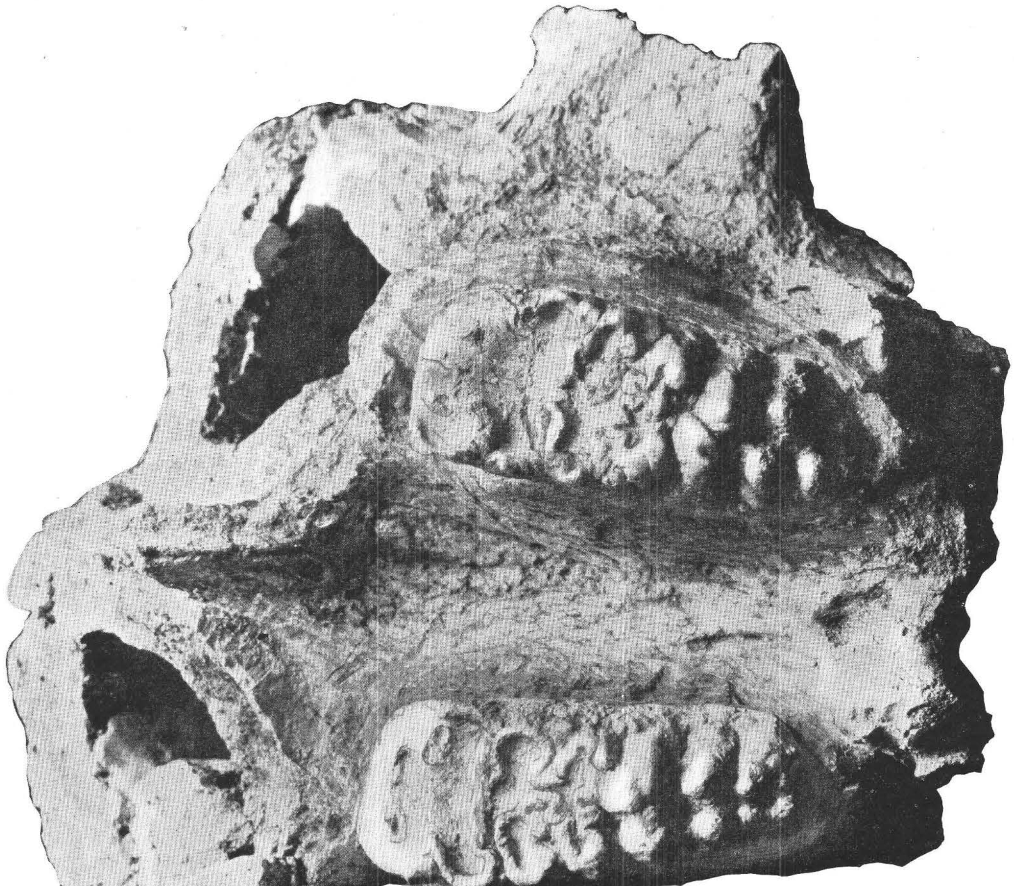


a

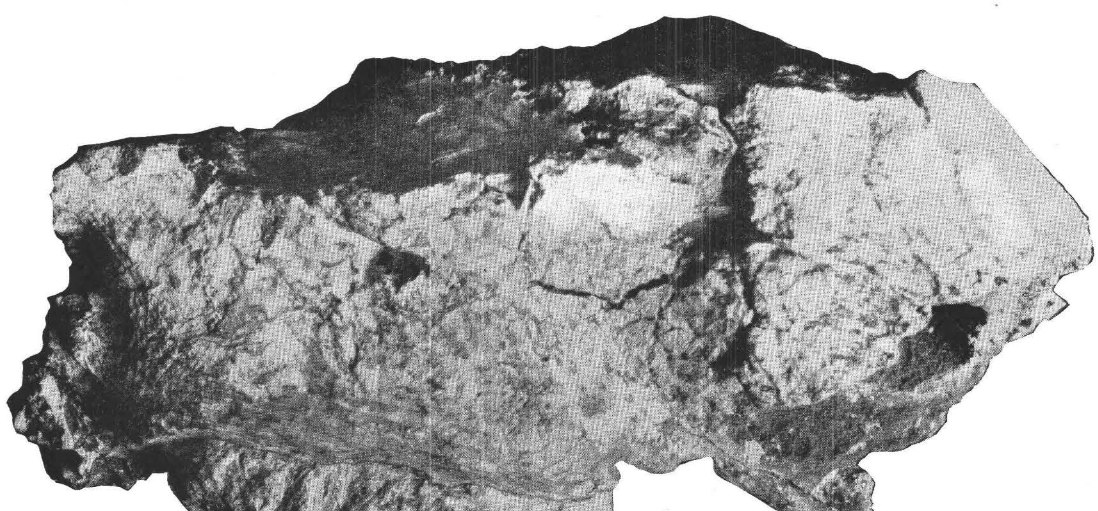
b

FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Left lower jaw of type of *Stegomastodon arizonae* Gidley, n. sp. (No. 10707, U. S. Nat. Mus.). About one-third natural size. a, View from above; b, inner side view



a

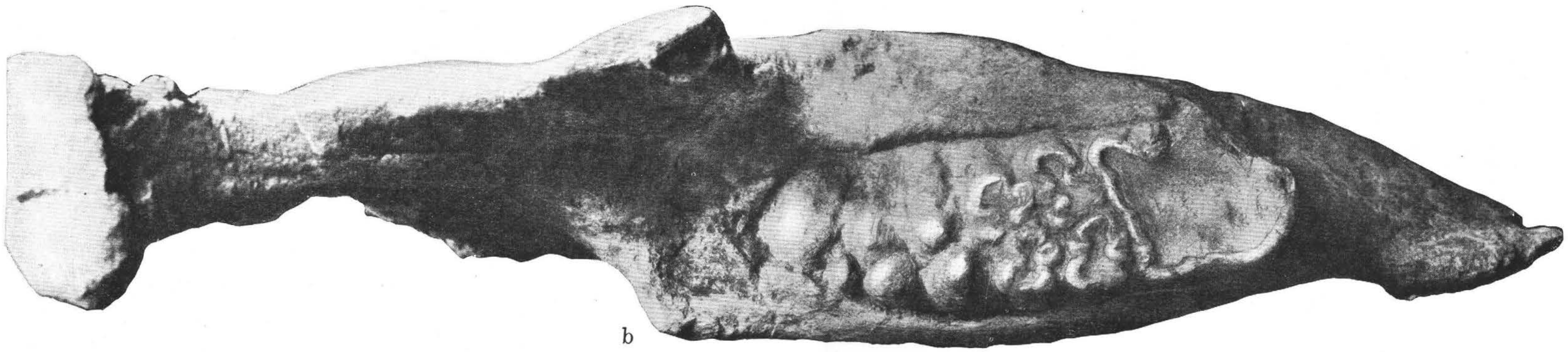


b

FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Portion of skull of *Stegomastodon arizonae* Gidley, n. sp. (No. 10556, U. S. Nat. Mus.). About two-sevenths natural size. a, Palate view; b, view from right side

a



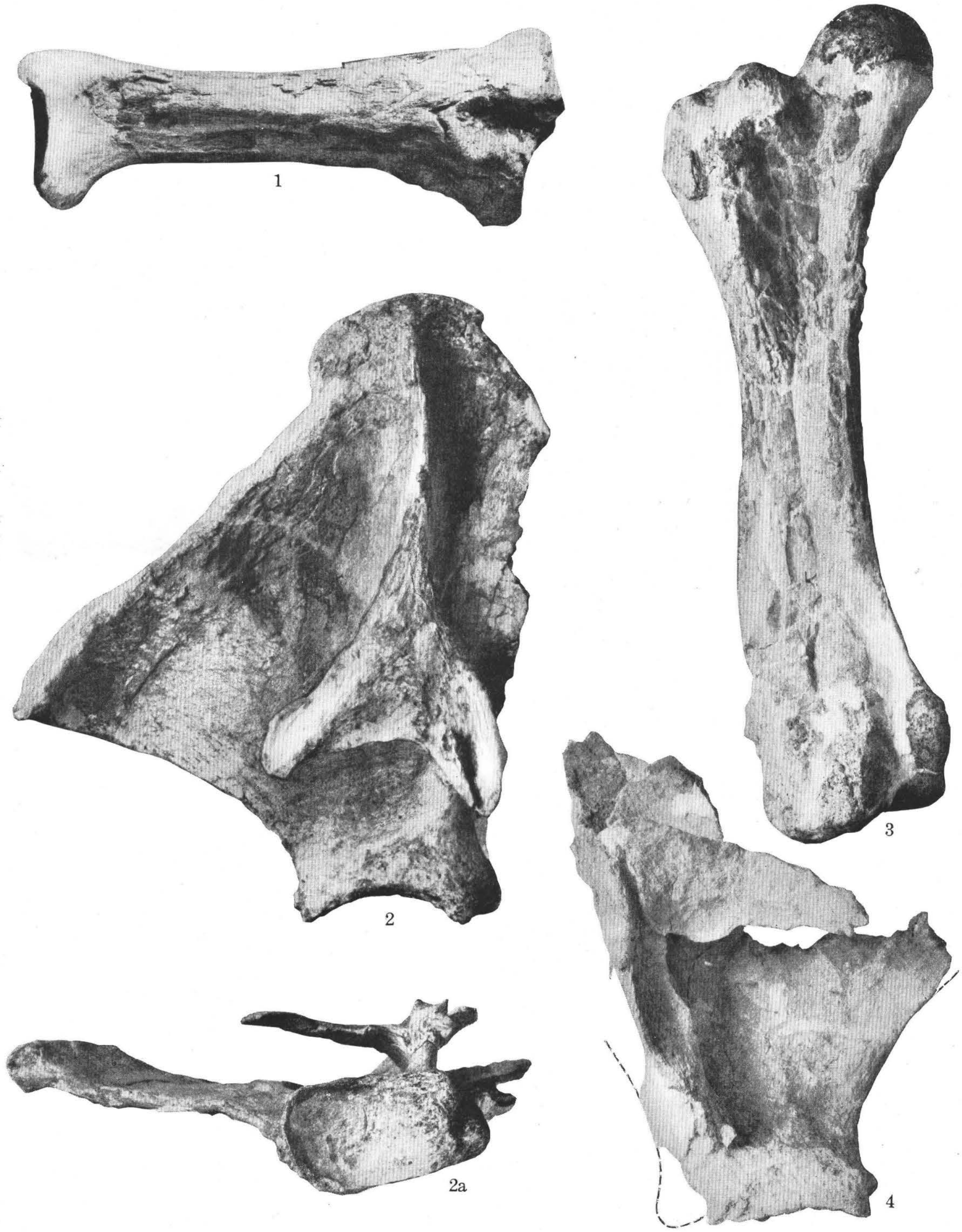
b

FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Left lower jaw of *Stegomastodon arizonae* Gidley, n. sp. (No. 10556, U. S. Nat. Mus.). About two-sevenths natural size. a, Outer side view; b, view from above

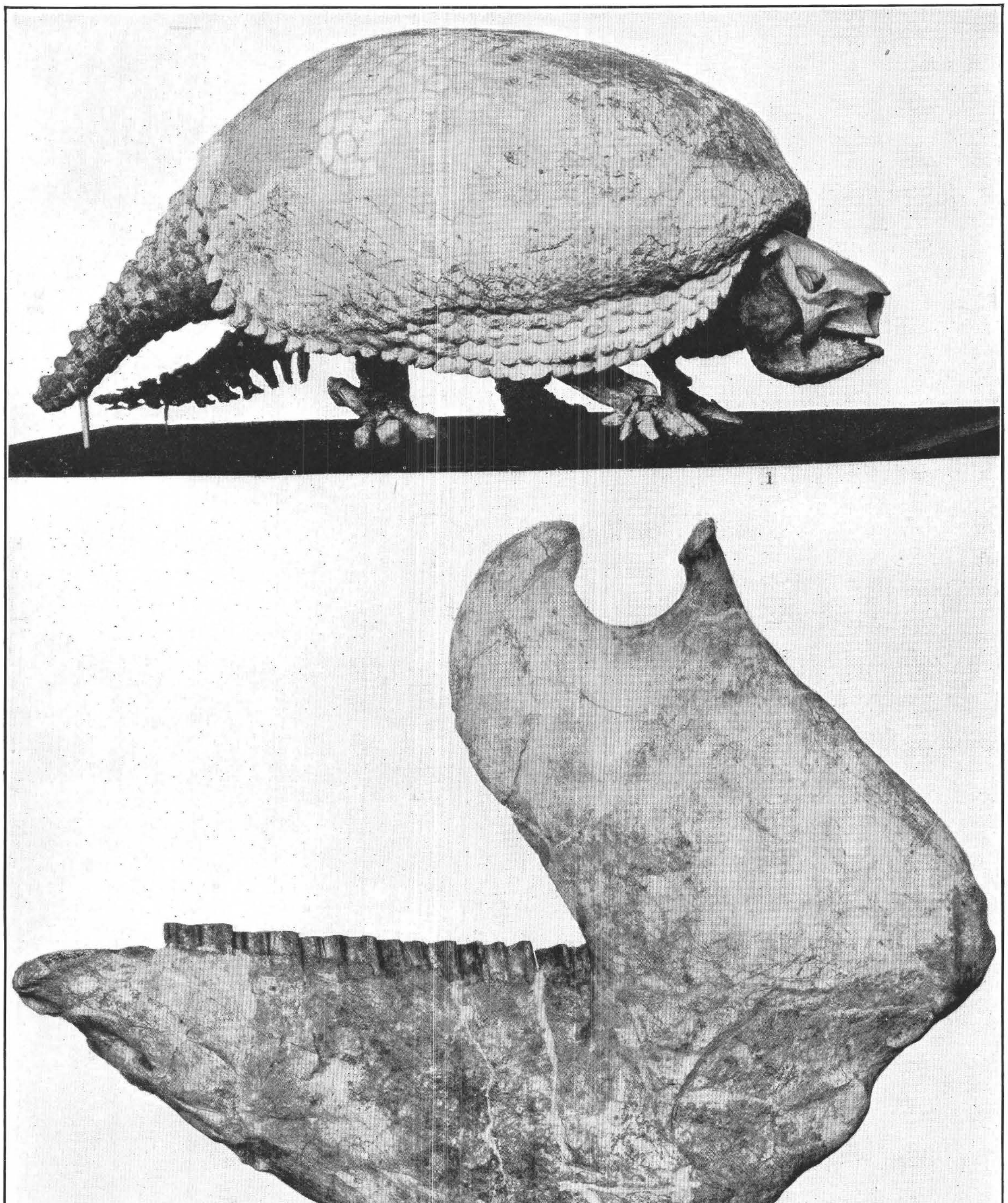
FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Bones of *Stegomastodon arizonae* Gidley, n. sp. All about one-sixth natural size. 1–3, Type (No. 10707, U. S. Nat. Mus.); 4, No. 10556, U. S. Nat. Mus. 1, Right humerus, anterior view; 1a, same, outer side view; 2, right ulna, outer side view; 2a, same, anterior view; 3, right radius, anterior view; 4, distal half of left humerus, anterior view



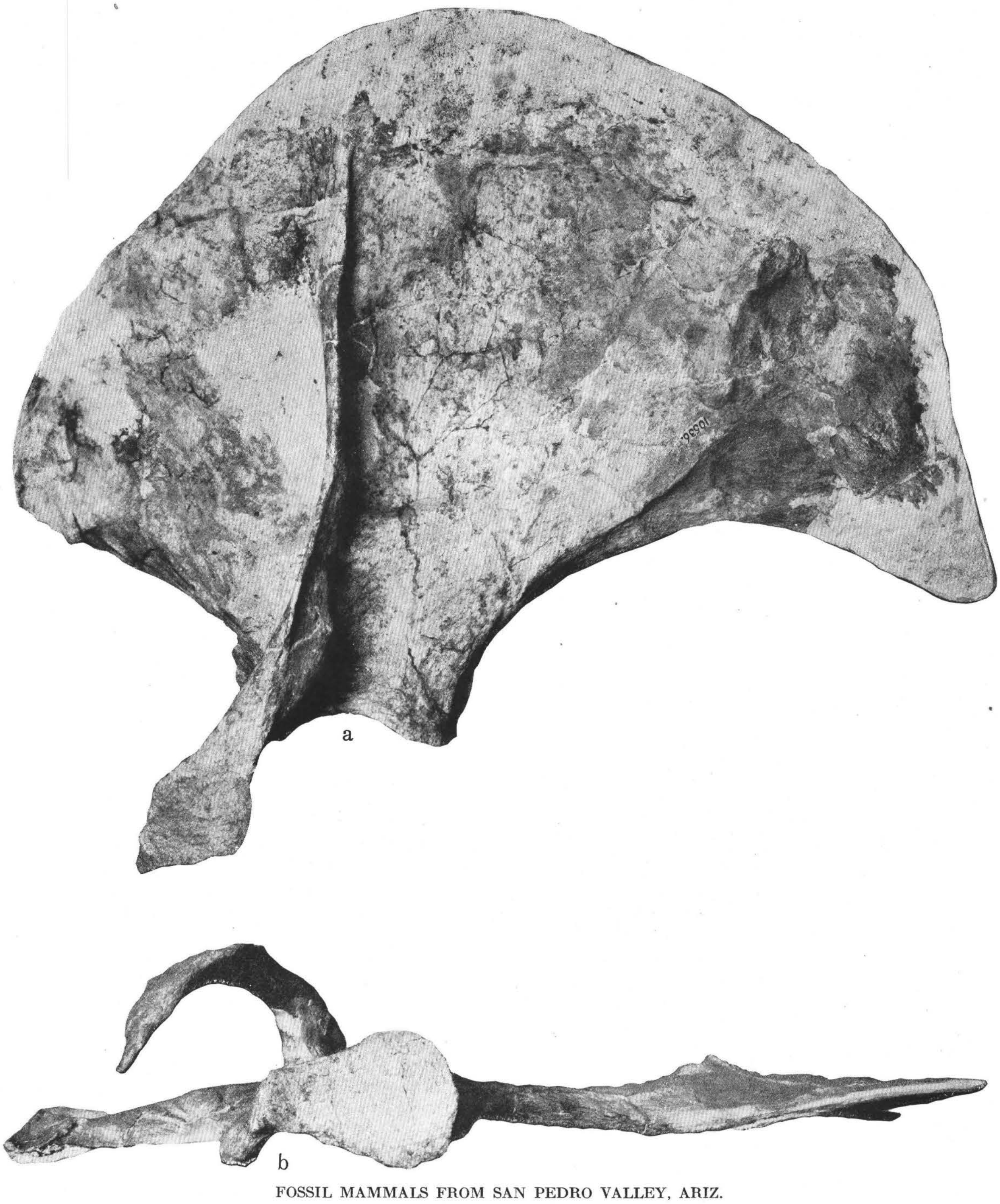
FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Bones of *Stegomastodon arizonae* Gidley, n. sp. 1–3, Type (No. 10707, U. S. Nat. Mus.); 4, No. 10556, U. S. Nat. Mus. All about one-eighth natural size. 1, Left tibia, anterior view; 2, right scapula, outer view; 2a, same, view from below; 3, right femur, anterior, slightly oblique view; 4, portion of left scapula, outer view



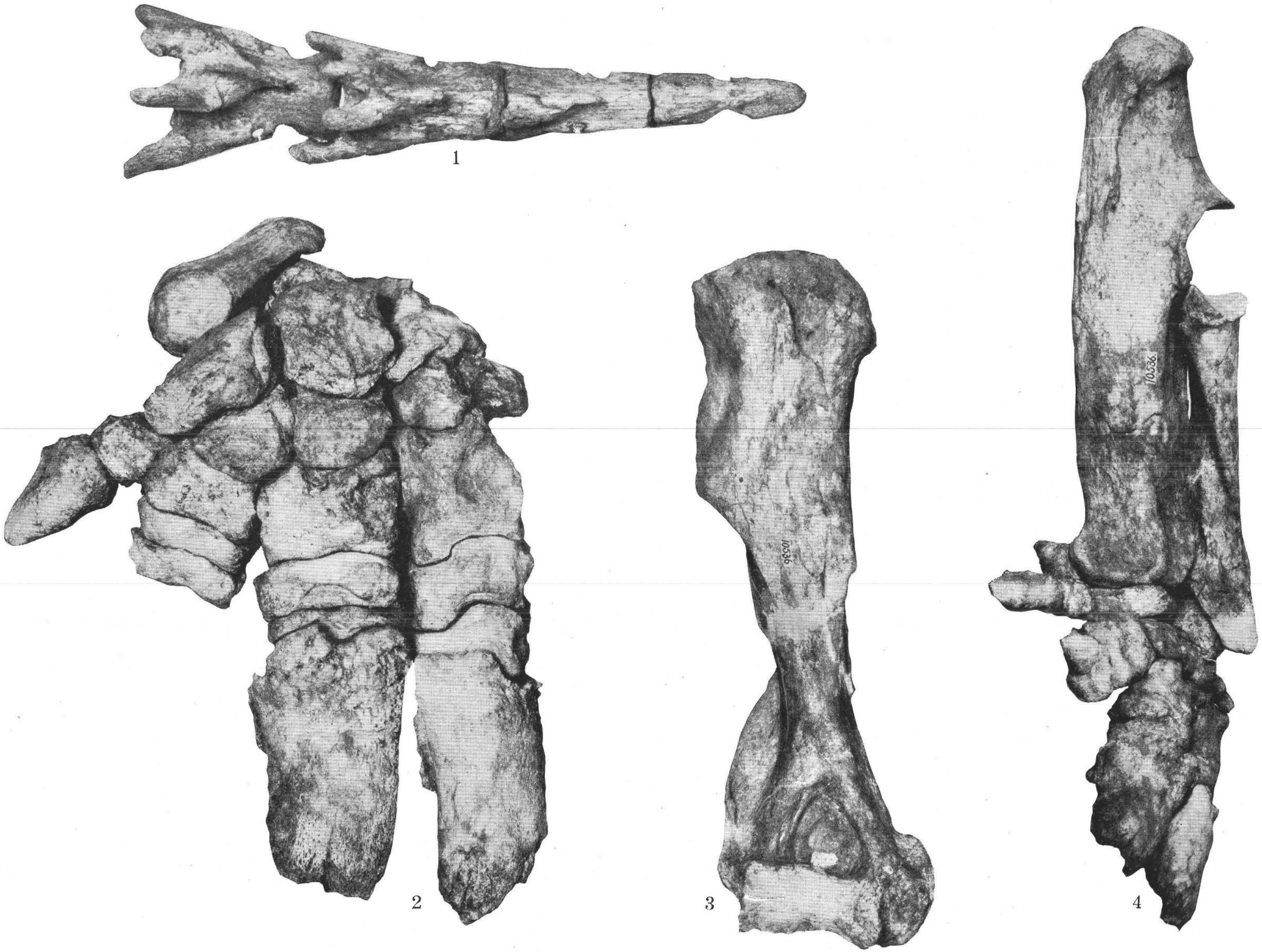
FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Glyptotherium arizonae Gidley, n. sp. 1, Skeleton, composite of three individuals, Nos. 10536 (type), 10537, and 10336, U. S. Nat. Mus.; about one-sixteenth natural size. 2, Left lower jaw of type (No. 10536), outer side view; about one-half natural size



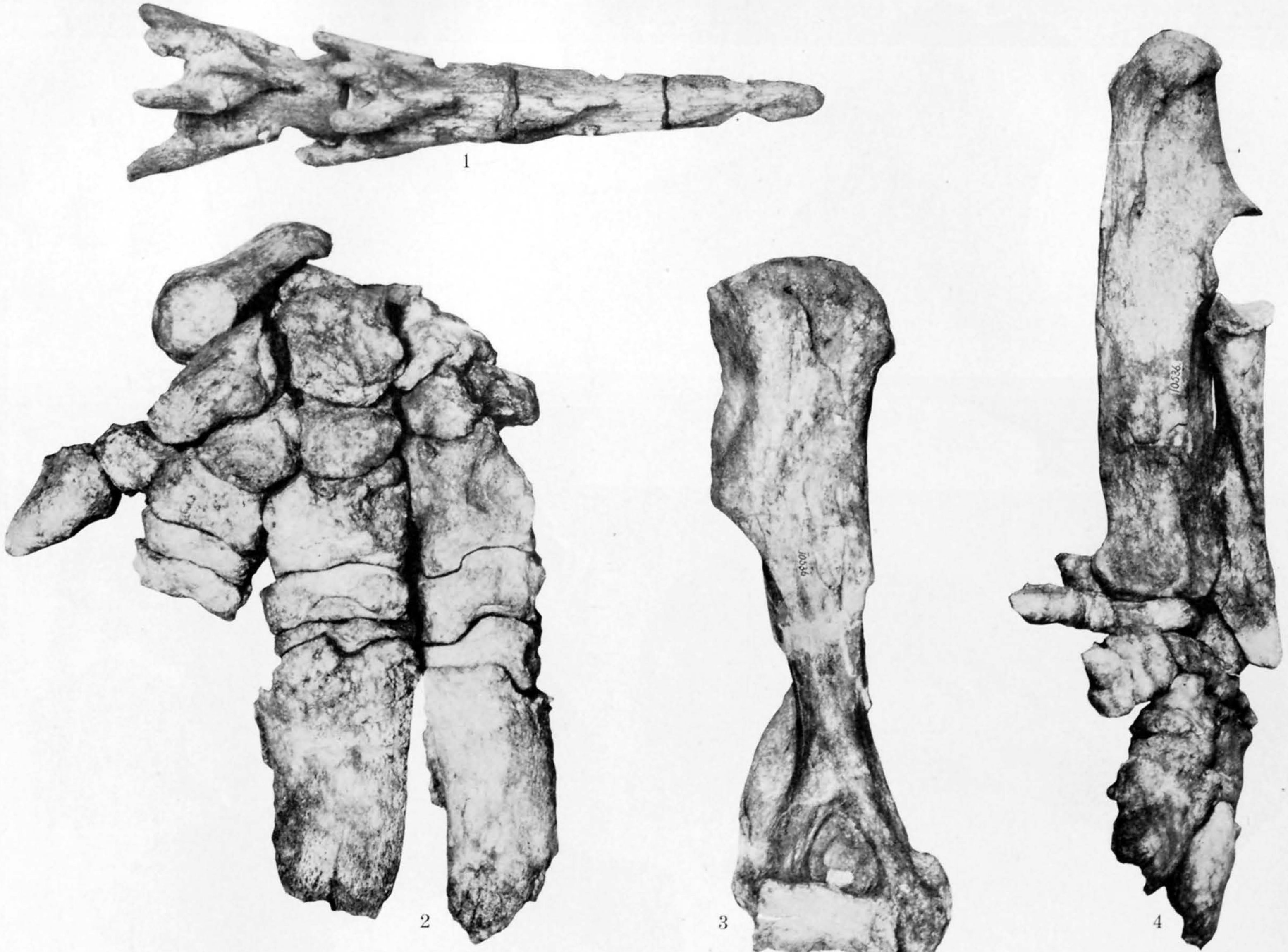
FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Left scapula of *Glyptotherium arizonae* Gidley, n. sp., type (No. 10536, U. S. Nat. Mus.). About one-third natural size. a, Outer side view; b, view from below



FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Bones of *Glyptotherium arizonae* Gidley, n. sp. 1, Distal four caudal vertebrae of No. 10537, dorsal view, about one-fourth natural size; 2, right fore foot of type (No. 10536), plantar view, about one-half natural size; 3, right humerus, anterior view, about one-third natural size; 4, right fore arm and fore foot of type, outer side view, about one-third natural size



FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Bones of *Glyptotherium arizonae* Gidley, n. sp. 1, Distal four caudal vertebrae of No. 10537, dorsal view, about one-fourth natural size; 2, right fore foot of type (No. 10536), plantar view, about one-half natural size; 3, right humerus, anterior view, about one-third natural size; 4, right fore arm and fore foot of type, outer side view, about one-third natural size

FOSSIL MAMMALS FROM SAN PEDRO VALLEY, ARIZ.

Elements of tail sheath of *Glyptotherium arizonae* Gidley, n. sp., paratype (No. 10537, U. S. Nat. Mus.). All about one-third natural size. 1, Terminal tube of tail sheath, dorsal view; 2, seventh ring of tail sheath, dorsal view; 3, sixth ring of tail sheath, dorsal view; 4, fourth ring of tail sheath, dorsal view; 5, anterior view of fourth ring of tail sheath with its corresponding vertebra and chevron in place

PLEISTOCENE PLANTS FROM NORTH CAROLINA

By Edward Wilber Berry

INTRODUCTION

The field work upon which this report is based was done in 1906 and 1907 as a part of the cooperative study of the Atlantic Coastal Plain, under the direction of the late William Bullock Clark. Associated with the writer in this work were L. W. Stephenson, B. L. Miller, jr., and J. E. Pogue. Preliminary accounts of the plants collected were published in 1907 [1] and 1909.[2]

As has been frequently emphasized, the study of the Pleistocene floras in this country is in an exceedingly backward state as measured by the volume and precision of our knowledge of Pleistocene floras in Europe. Researches in Pleistocene geology in North America have been confined almost entirely to glaciology, and the problem of the correlation of the glacial deposits with those outside the glaciated area has not been solved, nor is there any general agreement regarding the genesis of the Pleistocene deposits south of the terminal moraines. The present account of what is known of the Pleistocene flora of North Carolina and the conclusions that may be legitimately derived from it is offered in the hope that it may stimulate an interest in a neglected field of research and form a small part of the evidence upon which to base future more comprehensive conclusions and generalizations.

A word of explanation regarding the illustrations is required. Nearly all of them have been made from leaves preserved as carbonaceous films in the peaty clays. These specimens were carefully washed out, and blue prints were made directly from them. Outlines and as much of the venation as could be seen were inked on the blue prints, which were then bleached. This procedure made it possible to handle a much larger amount of material and prevented any possible damage to the exceedingly fragile specimens, which were mounted on cards or between glass. The accompanying drawings were made from tracings of the original nature prints.

[1] Berry, E. W., Contributions to the Pleistocene flora of North Carolina: Jour. Geology, vol. 15, pp. 338–349, 1907.

[2] Berry, E. W., Additions to the Pleistocene flora of North Carolina: Torreya, vol. 9, pp. 71–73, 1909.

GEOLOGY OF THE PLEISTOCENE IN NORTH CAROLINA

The Pleistocene formations of North Carolina were discussed in detail by Stephenson [3] in 1912. Five formations, mapped largely by their topographic form and constituting five terrace plains with seaward-facing scarps and reentrants up the stream valleys, were recognized. These are, from youngest to oldest; the Pamlico, Chowan, Wicomico, Sunderland, and Coharie. Among these formations identifiable fossil plants have been found only at a single locality in the Wicomico, at two localities in the Chowan, and at two localities in the Pamlico.

The Wicomico locality is 1¼ miles east of Weldon, in Northampton County, where the following section is exposed, according to Stephenson:

Section 1¼ miles east of Weldon, N. C.

	Feet
Yellow more or less sandy clay, largely concealed by vegetation	35
Yellow pebbly argillaceous sand	2
Lenses of yellow clay with leaves	½
Yellow very coarse pebbly arkosic sand	2½

The principal Chowan locality is along the right bank of Neuse River 79⅔ miles above New Bern and 4½ miles above Seven Springs, in Wayne County, where the following section is exposed:

Section on Neuse River above Seven Springs, N. C.

	Feet
Clay loam grading down into sandy loam	4
Coarse white and yellow sand with gravel layers and boulders in lower portion	7
Tough blue clay interstratified with lignitic and leaf layers 2 to 3 inches thick	3

Published accounts of the fossil plants from this section have alluded to it as station 850.

The second Chowan locality is at Dupree Landing, on the right bank of Tar River about 14 miles above Greenville, in Pitt County, where the following section is exposed in a depression in the Patuxent formation:

Section at Dupree Landing, N. C.

	Feet
Sandy loam and argillaceous sand with pebbles along base	6
Lignite	0–3

[3] Stephenson, L. W., The Coastal Plain of North Carolina: North Carolina Geol. and Econ. Survey, vol. 3, pp. 266–290, 1912.

The Pamlico formation, whose surface constitutes the lowest terrace plain of eastern North Carolina, contains fossil plants at Old Mill Landing, on the left bank of Roanoke River 8 miles above Williamston, in Bertie County, where the following section is exposed:

Section at Old Mill Landing, N. C.

	Ft.	in.
Surface loam grading down into buff sand with small pebbles interstratified with argillaceous layers	10	
Fine gravel		8–10
Concealed	3	6
Gravel	1	
Cross-bedded sand	1	
Gravel		6
Yellow sandy clay	5	
Dark micaceous clay with plants	0–1	

The second Pamlico locality is a low exposure on the right bank of Neuse River 10 or 12 miles below New Bern, in Craven County, from which only the remains of the bald cypress and pine have been recorded.

As regards the correlation of these formations with the Pleistocene formations of the adjacent States it may be stated that all can be traced for long distances in the Coastal Plain, both north and south of North Carolina. In South Carolina these formations and their corresponding terrace plains have not been definitely named. The Wicomico formation in North Carolina is a direct southward continuation of the Wicomico formation of Maryland and Virginia. The Chowan and Pamlico together correspond to what has been called the Talbot formation in Maryland and Virginia, the Chowan corresponding to the older and the Pamlico to the younger part of the Talbot, and it is probable that detailed work would show a corresponding division of the Talbot in Virginia and on the Eastern Shore of Maryland. (See fig. 5.)

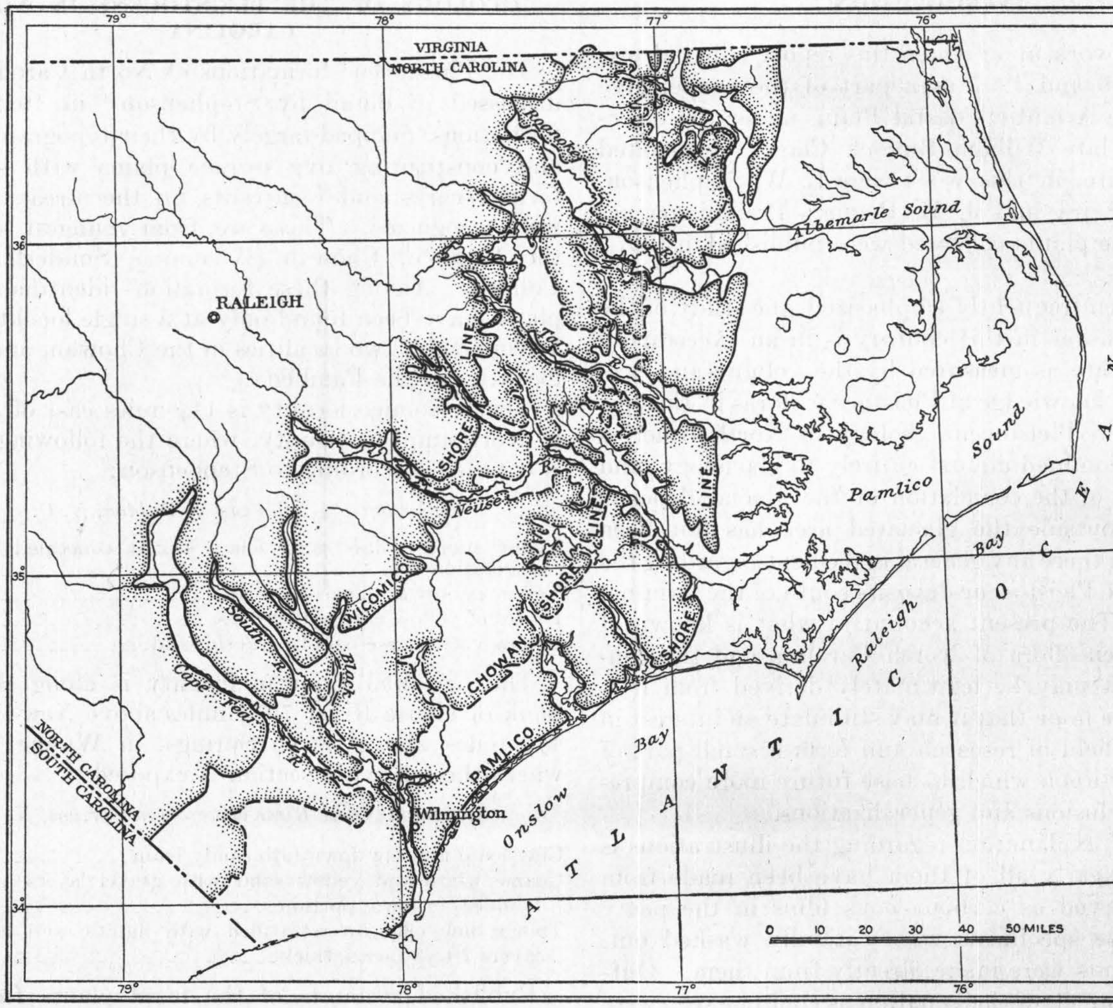


FIGURE 5.—Map showing the Pamlico, Chowan, and Wicomico coasts of North Carolina

CHARACTER OF THE FLORA

The flora here described contains more or less certainly determined remains of 48 species, representing 30 genera in 23 families and 17 orders. All but two conifers, representing the genera *Pinus* and *Taxodium*, are angiosperms or flowering plants, and of these all belong to the class Dicotyledonae except fruits representing a grass and a pond weed.

None of the recorded species are forms that appear at all out of place in a North Carolina flora, although several no longer exist at or near the localities where the fossils were found. Two species of willows, one of birch, two of oaks, two of crab apple, two of hawthorn, one of *Dendrium*, and one of *Vaccinium* are described as new and consequently extinct species. These new forms constitute nearly 23 per cent of the whole flora, a proportion that is somewhat misleading, for the following reasons: One of the oaks is obviously an abnormality or hybrid and not a true botanical species; the two species of *Malus* and the birch are not very precisely differentiated; and the two species of *Crataegus* belong to a genus that appears to have undergone rapid mutation in recent times and to be of uncertain value. This leaves an extinct species of *Quercus* and one of *Dendrium* that I regard as satisfactory and a species of *Vaccinium* that may be authentic or may possibly represent an abnormality.

Both the oak and the *Dendrium* represent Pleistocene forms, each regarded as ancestral to two existing species of different environmental requirements. Thus the true percentage of extinct species may really be about 4 instead of nearly 23.

Nearly all the species represented are trees or shrubs. The only herbaceous forms are *Sparganium*, *Chaetochloa*, and *Polygonum*, represented by fruits and not by leaves. Thus in Pleistocene time, as to-day in the backwaters of rivers and estuaries of the Coastal Plain of North Carolina, the bulk of the leaves that were preserved in the sediments were the leaves of trees.

The most abundantly represented forms in this Pleistocene flora are the bald cypress, the river birch, the beech, various oaks, and the button ball. The oaks are remarkable for both their individual abundance and variety, ten species being recorded, representing both dry and wet soil forms. The most abundant of these are the wet-soil forms *Quercus nigra*, *Q. phellos*, and *Q. michauxii*, although *Quercus predigitata* is about equally abundant.

All of North America north of the terminal moraine, with the exception of a few nunataks or small ice-free areas that projected above the continental ice sheet and a few ice-free regions, the largest known of which were in central and northern Alaska, have been colonized by vegetation since the end of the Wisconsin glaciation, which is considered to have been from 10,000 to 20,000 years ago.

A great deal of misconception has existed regarding the severity of glacial climates and their effect on the Tertiary vegetation of North America. There is little doubt that the present major floristic regions were well marked toward the end of the Tertiary period, particularly as regards the separation of the eastern mesophytic region from that of the Pacific region by the intervening area, consisting mainly of prairie or grass land, but including at the south desert or semidesert.

During the maximum extent of the ice there must have been considerable crowding and competition between the native flora and that which formerly existed in the glaciated region. That there was an actual zonal arrangement of climatic belts south of the ice front seems very doubtful. Even in the immediate vicinity of the ice front there was probably no continuous barren ground or tundra zone inhabited by arctic vegetation. None of the evidence as yet disclosed in the Pleistocene floras of North America, although admittedly very incomplete, shows an appreciable lowering of temperature at any great distance away from the ice front. This may, of course, be due to the fact that the bulk of the Pleistocene plants so far discovered have come from relatively low altitudes and mostly from the Coastal Plain.

The plant localities in the Pleistocene area of North Carolina are about 425 miles south of the terminal moraine on the Atlantic coast, about 400 miles south of its position in southern Ohio, about 475 miles southeast of it in Indiana, and slightly over 600 miles east-southeast of its southernmost limit in southern Illinois.

Unless there were a secular lowering of temperature amounting to a cataclysmal change, which is highly improbable, the effect of the ice sheet on the vegetation of low-lying coastal lands several hundred miles away would not be detectable. The coastal region of North Carolina during the Pleistocene epoch appears to have been densely forested and to have received an abundant rainfall, both factors that would tend to stabilize the climate and prevent extremes. By comparison with areas that have been critically studied, like the Dismal Swamp, it may be concluded that the climate along the Pleistocene coast of North Carolina, except where the normal climate was disturbed by violent and long-continued winds, was highly favorable for a vigorous and dense forest cover, with slight daily variations of temperature, a long growing season, heavy and well-distributed rainfall, a uniformly high humidity, and freedom from violent frosts.

The cypress swamps along the Pleistocene coast clearly indicate that it was fringed by barrier beaches similar to those existing at the present time along the northern Carolina coast, and that in the inclosed sounds behind these beaches the salinity of the water was kept down by the volume of river water entering them; otherwise salt marshes would have gradually replaced the swamp forests.

The plant remains discovered in the North Carolina Pleistocene show no elements that can be definitely interpreted as northern forms, and although the horizons at which they occur can not be precisely correlated with glacial chronology, three horizons are represented—namely, the Wicomico, Chowan, and Pamlico—and it is not likely that all the periods of coastal subsidence and the deposition of coastal terraces should have coincided with interglacial stages, particularly as most of these terrace deposits, both here and elsewhere along the Atlantic coast, contain what appear to be ice-borne boulders, including some of considerable size.

These boulders at certain localities have been explained as indicating material dropped by icebergs from the north. This might be true for the erratics found in the "banks" of eastern North Carolina, though such an explanation of the presence of such erratics seems improbable. It is certainly not an adequate explanation of their presence at many places in the Pleistocene deposits, as, for example, in the drainage basin of Potomac River. I believe that these are to be explained as borne by river ice, although the smaller ones may have been carried in the roots of drifted trees. If this explanation is sound it indicates a considerable severity of climate, with the formation of much ice, in the uplands along the Alleghany Mountains, which in fact seems to be necessary to explain the present stranded floras and faunas on the higher peaks even as far south as western North Carolina. In regions where boulders are common in the subsoil, as is in a measure true of the Piedmont district of North Carolina, trees encompass many of the boulders in their root systems, and if such trees are overturned by windstorms within reach of rivers in flood periods such stones may be carried long distances. I collected a cobble in 1909 from the root of an Upper Cretaceous tree lignified in the Tuscaloosa formation of Alabama, which is an objective demonstration of this process in the past.

After the storm of August, 1924, which uprooted many large trees in southeastern Connecticut, nearly every tree had one or more boulders tightly clasped by the roots, and these boulders already once glaciated would, if stream transportation had been available, have been carried out and eventually come to rest in fine marine muds. The largest boulder seen was in the roots of a tall pine 18 inches in diameter and had dimensions of 55 by 19 by 20 inches.

The following 27 Pleistocene species out of a total of 48, or considerably more than half, are forms that in the existing flora range long distances north and south of North Carolina:

Sparganium sp.	Polygonum sp.
Hicoria ovata.	Liriodendron tulipifera.
Hicoria glabra.	Liquidambar styraciflua.
Populus cf. P. heterophylla.	Rubus sp.
Carpinus caroliniana.	Malus pseudoangustifolia.
Betula nigra.	Malus coronariafolia.
Fagus americana.	Cercis canadensis.
Quercus velutina.	Ilex opaca.
Quercus prinus.	Vitis sp.
Quercus palustris.	Xolisma ligustrina.
Quercus alba.	Vaccinium corymbosum.
Quercus lyrata.	Viburnum molle.
Celtis occidentalis.	Viburnum nudum.
Platanus occidentalis.	

Many of these species have extended their range northward into New England, southern Canada, and the States north of Ohio River since the retreat of the Wisconsin ice sheet, but at its maximum extent they appear to have approached it rather closely, at least in the Coastal Plain, where some of them are recorded as far north as New Jersey, and several were growing in southern Maine at a time when the rivers were still encumbered with valley ice. It is exceedingly difficult to evaluate the Pleistocene fossil plants of the Middle Atlantic States, because most of the species range long distances to the north and south, and considerable extensions or contractions of their range might have taken place without being registered in this middle region.

None of the North Carolina plants are definitely northern types or forms that in the existing flora are approaching their southern limit of range in the Carolina region. Quite the reverse is true. Of a total of 48 recorded species the following 14 are at or near their northern limit of range as judged by the existing flora:

Pinus serotina.	Ulmus alata.
Taxodium distichum.	Planera aquatica.
Hicoria aquatica.	Crataegus spathulatoides.
Quercus nigra.	Persea pubescens.
Quercus michauxii.	Nyssa biflora.
Quercus phellos.	Dendrium pleistocenicum.
Quercus predigitata.	Vaccinium arboreum.

This is nearly 30 per cent of the known Pleistocene flora of North Carolina and, if it means anything, indicates a milder climate than prevails in that area at the present time.

It is true that there is considerable evidence that certain species, such as *Taxodium distichum* and *Planera aquatica*, are becoming more restricted in the Coastal Plain at the present time, but this restriction appears to have followed a late Pleistocene or post-glacial extension northward, and certainly, for the Coastal Plain flora as a whole, the main movement has been one of a marked expansion northward on the heels of the retreating ice sheet.

More than half of the fossil plants from North Carolina are forms that in the modern flora require wet habitats. These forms are indicated in the accompanying table. Some of them, such as *Pinus serotina*, *Taxodium distichum*, *Sparganium*, *Hicoria aquatica*, *Quercus nigra*, *Quercus phellos*, *Quercus palustris*, *Planera aquatica*, and *Nyssa biflora*, prefer in modern times partly or permanently inundated bottoms. Others, like *Salix*, *Betula nigra*, *Liquidambar styraciflua*, *Quercus michauxii*, and *Ilex opaca*, get along with a less constantly flooded substratum. Others not enumerated among the 25 wet species, like *Fagus americana*, *Quercus lyrata*, *Quercus alba*, *Liriodendron tulipifera*, and *Cercis canadensis*, are woodland forms of deep, moist soils.

The dry-soil species are fewer in number and include *Hicoria glabra*, *Quercus velutina*, *Quercus prinus*, *Celtis occidentalis*, and *Vaccinium arboreum*. There are several forms that may be considered as occurring on both wet and dry soils. In this category are *Quercus predigitata*, *Ulmus alata*, *Rubus*, *Vitis*, *Xolisma ligustrina*, and *Dendrium pleistocenicum*.

The Pleistocene flora of North Carolina fulfills the requirements that might have been expected from the areal distribution of the deposits in which it has been found. Each deposit consists of sediments laid down in an estuary, and most of the fossil plants are those that might be expected to occur in the bottoms of the lower courses of estuary streams. The few dry-ground forms represented as fossils either grew near at hand on high and dry river bluffs or were brought from the more remote upper courses of these streams into the basin of sedimentation occasionally, as through the agency of floods.

The map showing the shore lines of the seas in which the formations were laid down (fig. 5) brings out with notable clearness the estuary character of the fossiliferous localities, especially in Bertie, Pitt, and Wayne counties.

Plant geographers have always been interested in the representatives of the eastern North American deciduous-forest region which are found in the uplands of southern Mexico, Guatemala, and Costa Rica, and which obviously indicate a once continuous area of distribution, since broken by the conditions that produced the wide belt of arid country now found in the southwestern United States and northern Mexico.

There is as yet little evidence for dating this southward extension of the mesophytic temperate flora of North America into the Tropics. Without predicating climatic changes for which there is no warrant in the available evidence we must conclude that it could not have occurred before the elevation of these Central American regions above the tierra caliente, or tropical and subtropical altitudinal zones. This event is believed to have occurred in late Tertiary time, although the distribution of marine faunas shows clearly numerous earlier changes of level

Among these upland genera occurring in Central America might be enumerated *Abies*, *Pinus*, *Taxodium*, *Liquidambar*, *Quercus*, *Juniperus*, *Alnus*, *Salix*, *Populus*, *Celtis*, *Tilia*, *Arbutus*, *Morus*, *Vitis*, *Hicoria*, *Fraxinus*, *Rhus*, *Juglans*, *Ulmus*, *Prunus*, *Cornus*, *Cercis*, *Staphylea*, *Platanus*, *Arctostaphylos*, *Carpinus*, and perhaps others. There is good reason for believing that certain of these genera accomplished this southward radiation early in the Tertiary period, if not in the Upper Cretaceous, and probably some, such as the Ulmaceae, invaded North America from the south.

Celtis occurs in the Eocene and *Alnus* and *Rhus* in the Pliocene of South America; *Liquidambar* is found in the Miocene of southern Mexico; and there is every reason to believe that of the genera enumerated above *Pinus*, *Liquidambar*, *Alnus*, *Celtis*, *Rhus*, and *Juglans* represent an old element in this southern region. Others that appear to be somewhat more recent are *Taxodium*, *Quercus*, *Abies*, *Juniperus*, *Salix*, *Populus*, *Vitis*, and possibly *Ulmus*. It is difficult to imagine physical conditions different enough from the present to permit Pleistocene dispersal, and on the other hand it is difficult to imagine species like those of *Carpinus*, *Platanus*, and *Taxodium* existing practically unchanged for a long time in two segregated regions of rather different environments.

An attempt to portray the possible floristic regions at the period of maximum extent of the continental ice is shown on the accompanying sketch map (fig. 6). It is of course much generalized, being based upon very inadequate knowledge, and it synthesizes a too long and too constantly changing period of time. It differs from previous maps of this nature in restricting the possible belt of northern coniferous and arctic plants to certain unspecified situations in the immediate vicinity of the ice front, and, except for a restriction of the central prairie region, in regarding the eastern and western North American mesophytic regions as having been much as they are at the present time, and with much the same association of species.

Habitat and range of Pleistocene plants from North Carolina

	Habitat				Range	
	Wet	Dry	Both wet and dry	Woods	Long distance both north and south	Near northern limit of range
Coniferophyta:						
Pinales:						
Pinaceae:						
Pinus serotina Michaux	×					[a] ×
Cupressinaceae:						
Taxodium distichum (Linné) L. C. Richard	×					×
Angiospermophyta:						
Monocotyledonae:						
Pandanales:						
Sparganiaceae:						
Sparganium sp	×					
Graminales:						
Poaceae:						
Chaetochloa sp						
Dicotyledonae:						
Juglandales:						
Juglandaceae:						
Hicoria ovata (Miller) Britton	×				×	
Hicoria glabra (Miller) Britton		×			×	
Hicoria aquatica (Michaux son) Britton	×					×
Salicales:						
Salicaceae:						
Populus cf. P. heterophylla Linné	×				×	
Salix viminalifolia Berry	×					
Salix bebbianaformis Berry	×					
Fagales:						
Betulaceae:						
Carpinus caroliniana Walter	×				×	
Betula nigra Linné	×				×	
Betula pseudofontinalis Berry						
Fagaceae:						
Fagus americana Sweet				×	×	
Quercus nigra Linné	×				×	×
velutina Lamarck		×			×	
abnormalis Berry					×	
prinus Linné		×			×	
michauxii Nuttall	×				×	×
palustris DuRoi	×				×	
alba Linné				×	×	
lyrata Walter	×				×	×
phellos Linné	×				×	×
predigitata Berry			×		×	×
Urticales:						
Ulmaceae:						
Ulmus alata Michaux			×		×	×
Celtis occidentalis Linné		×			×	
Planera aquatica (Walter) Gmelin (?)	×				×	×
Platanales:						
Platanaceae:						
Platanus occidentalis Linné	×				×	
Polygonales:						
Polygonaceae:						
Polygonum	×				×	
Ranales:						
Magnoliaceae:						
Liriodendron tulipifera Linné				×	×	
Rosales:						
Hamamelidaceae:						
Liquidambar styraciflua Linné	×				×	
Rosaceae:						
Rubus sp			×		×	
Pomaceae:						
Malus pseudo-angustifolia Berry					×	
Malus coronariafolia Berry					×	
Crataegus spathulatoides Berry	×					×
Crataegus coccineafolia Berry						
Caesalpiniaceae:						
Cercis canadensis Linné				×	×	
Sapindales:						
Ilecaceae:						
Ilex opaca Aiton	×				×	
Rhamnales:						
Vitaceae:						
Vitis sp			×		×	

[a] At northern limit

Habitat and range of Pleistocene plants from North Carolina—Continued

	Habitat				Range	
	Wet	Dry	Both wet and dry	Woods	Long distance both north and south	Near northern limit of range
Angiospermophyta—Continued.						
Dicotyledonae—Continued.						
Thymeleales:						
Lauraceae:						
Persea pubescens (Pursh) Sargent	×					×
Umbellales:						
Cornaceae:						
Nyssa biflora Walter	×					×
Ericales:						
Ericaceae:						
Xolisma ligustrina (Linné) Britton			×		×	
Dendrium pleistocenicum Berry			×			×
Vacciniaceae:						
Vaccinium corymbosum Linné	×				×	
spatulata Berry						
arboreum Marshall		×				×
Rubiales:						
Caprifoliaceae:						
Viburnum molle Michaux (?)				×	×	
Viburnum nudum Linné (?)	×				×	

FIGURE 6.—Map of North America showing the glaciated region, the floral geography, and source of the postglacial directions of dispersal (shown by arrows).

SYSTEMATIC DESCRIPTIONS

CONIFEROPHYTA

Order PINALES

Family PINACEAE

Genus PINUS Linné

Pinus serotina Michaux

Plate XLV, Figure 9

Pinus rigida Berry (not Miller), Jour. Geology, vol. 15, p. 339, 1907.

Leaves in threes, sometimes with sheaths preserved. These leaves were referred by me to *Pinus rigida* in 1907, as they seemed to be shorter than those of *Pinus serotina*. Subsequently cones were collected which in their smaller size, thinner scales, and slender, easily abraded prickles ally the leaves with *P. serotina* instead of *P. rigida*, which is more at home in the plant association recorded from the Coastal Plain of North Carolina.

Needles from the locality on Neuse River in Wayne County; needles and numerous cones from the locality on Tar River in Pitt County.

According to Pinchot and Ashe *Pinus serotina* in the existing flora does not extend up Tar River beyond Washington. It has not previously been found fossil.

Pinus rigida Miller in North Carolina is confined to the western Piedmont Plateau region and the mountain counties south of French Broad River, growing on dry, commonly sandy or gravelly ridges.

Pinus serotina Michaux, the pond, swamp, loblolly, or pocosin pine, is found on low peaty or wet sandy soils from North Carolina to Florida near the coast. In North Carolina it is practically confined to the Coastal Plain south of Albemarle Sound and reaches west to the fall line only in the valleys of Neuse and Cape Fear rivers.

Occurrence: Chowan formation, right bank of Neuse River, 4½ miles above Seven Springs, Wayne County; Dupree Landing, Tar River, Pitt County. Pamlico formation, below New Bern, Neuse River, Craven County.

Family CUPRESSINACEAE

Genus TAXODIUM Richard

Taxodium distichum (Linné) L. C. Richard

Plate XLV, Figures 1–8

Taxodium distichum Holmes, Elisha Mitchell Soc. Jour., vol. 2, p. 92, 1885.

Hollick, Maryland Geol. Survey, Pleistocene, pp. 218, 237, pl. 68, 1906.

Berry, Torreya, vol. 6, p. 89, 1906; Jour. Geology, vol. 15, p. 339, 1907; Am. Naturalist, vol. 43, pp. 432–434, figs. 1, 2, 1909; Am. Jour. Sci., 4th ser., vol. 29, p. 391, 1910; Torreya, vol. 10, p. 263, 1910; Plant World, vol. 16, pp. 39–45, figs. 1, 2, 1911; Am. Jour. Sci., 4th ser., vol. 34, p. 219, figs. 1, 2, 1912; Torreya, vol. 14, pp. 160, 162, 1914; U. S. Nat. Mus. Proc., vol. 48, p. 296, 1915; Torreya, vol. 15, p. 206, 1915; U. S. Geol. Survey Prof. Paper 98, p. 195, pl. 45, figs. 1–6, 1916; Jour. Geology, vol. 25, p. 662, 1917; Florida Geol. Survey Ninth Ann. Rept., p. 21, 1917; Washington Acad. Sci. Jour., vol. 14, p. 15, pl. 1, figs. 37–42; pl. 3, 1924.

It is probably not always possible to differentiate fossil specimens of the common bald cypress from the pond cypress, *Taxodium imbricarium* (for example, from cones or seeds alone); nevertheless it appears significant that among the very numerous Pleistocene occurrences of *Taxodium* that have been recorded, wherever the stumps or twigs are preserved, these represent *Taxodium distichum* and not *Taxodium imbricarium*. The numerous twigs and stumps found in the North Carolina Pleistocene belong to *Taxodium distichum*. It may be legitimately inferred from this circumstance that *Taxodium imbricarium* had not yet been differentiated at that time. If we assume that the pond cypress was already in existence, its absence from the fossil record at so many localities along the Atlantic coast is a strong argument for the method of genesis of the Pleistocene terraces advocated in the present report—namely, by marine control due to changes in relative level. If these terraces were purely the result of stream control and continental deposition, as is advocated in some quarters, it is almost impossible to conceive that somewhere the pond cypress would not have been preserved.

The bald cypress has a most interesting geologic history, and its immediate and scarcely distinguishable Tertiary ancestor attained a holarctic distribution in the later Tertiary.

The oldest beds in which the existing species has been definitely recognized are the Pliocene deposits along the Gulf coast of Alabama (Citronelle formation). It was exceedingly common at numerous widespread localities in southeastern North America during the Pleistocene epoch. Unfortunately it is not possible to correlate the outcrops at these localities with the chronology of the glaciated region to the north. Several of these Pleistocene localities are farther north or farther inland than the existing limits of range of the species, which is from southern Delaware and southern Maryland to extreme southern Florida and Texas. In North Carolina it is restricted to the Coastal Plain region. The leafy twigs and many seeds are present at the Neuse River locality in Wayne County; stumps, knees, and burls at the locality in Craven County; and leafy twigs, cone scales, and a staminate ament at the locality in Bertie County.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County. Pamlico formation, Old Mill Landing, Roanoke River, Bertie County, and below New Bern, Neuse River, Craven County.

ANGIOSPERMOPHYTA

Class MONOCOTYLEDONAE

Order PANDANALES

Family SPARGANIACEAE

Genus SPARGANIUM Linné

Sparganium sp.

Sparganium sp. Berry, Torreya, vol. 14, p. 160, 1914.

A nutlike fruit of some species of *Sparganium* is present at the locality on Neuse River in Wayne County. The determination was made for me by W. L. McAtee. It probably represents the existing *Sparganium androcladum* (Engelmann) Morong.

The genus *Sparganium* goes back to the Eocene and possibly earlier. It is common in the European Pleistocene and was presumably common in that of North America, although the records are few, including only this one and *Sparganium eurycarpum* Engelmann, recorded from the Wicomico formation at Washington, D. C.[4]

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Order GRAMINALES

Family POACEAE

Genus CHAETOCHLOA Scribner

Chaetochloa sp. Berry

Chaetochloa sp. Berry, Torreya, vol. 14, p. 160, 1914.

A caryopsis of some grass, identified by W. L. McAtee as a species of *Chaetochloa*, is contained in the collection from the Neuse River locality in Wayne County.

The genus *Chaetochloa* [5] includes *Setaria* Beauvois, *Ixophorus* Nash, and various species referred to *Panicum*, of which there are many species in our existing Coastal Plain flora.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Class DICOTYLEDONAE

Order JUGLANDALES

Family JUGLANDACEAE

Genus HICORIA

Hicoria glabra (Miller) Britton

Plate XLVI, Figures 1–4

Carya porcina Nuttall. Mercer, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 11, pp. 277, 281, figs. 8[4], [5], [12], [16], 1899.
Hicoria pseudoglabra Hollick, Maryland Geol. Survey, Pleistocene, p. 221, pl. 72, figs. 1, 16, 17, 1906.
Hicoria glabra Berry, Torreya, vol. 6, p. 89, 1906; Jour. Geology, vol. 15, p. 340, 1907; Torreya, vol. 9, p. 97, figs. 1–5, 1909; vol. 10, p. 264, fig. 1, 1910.

Fragmentary leaflets of this species are not uncommon at the locality on Neuse River in Wayne County, and several of these are figured. They are associated with several husks of nuts and one flattened nut and undoubtedly represent *Hicoria glabra*. Nuts of this species are not uncommon in the Pleistocene deposits of the Atlantic Coastal Plain and have been recorded from the Talbot formation of New Jersey and Maryland, from the Sunderland formation of Maryland, and from the Port Kennedy cave in Pennsylvania.

In the recent flora this species ranges from Maine to Minnesota and southward to Florida and Texas. In North Carolina, although found throughout the State on dry soils of ridges, it occurs chiefly in the Piedmont Plateau region, being uncommon in the mountains and rare in the Coastal Plain.

Hicoria is not uncommon in the Pleistocene. In addition to the two other species recorded from North Carolina, *Hicoria alba* occurs in Pennsylvania and Canada, *Hicoria villosa* occurs in Alabama, *Hicoria minima* occurs in Massachusetts, and several specifically undetermined nuts and leaflets have been recorded from Maryland and Alabama.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Hicoria ovata (Miller) Britton

Plate XLVI, Figures 6, 7

Carya ovata Miller. Mercer, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 11, p. 279, fig. 8[6], 1899.
Hicoria ovata Britton. Berry, Jour. Geology, vol. 15, p. 340, 1907.

Characteristic terminal leaflets of this species are present at the Neuse River locality in Wayne County. No nuts were collected, but nuts of this species found in the Port Kennedy cave in Pennsylvania were described by Mercer.

In the existing flora this species ranges from Quebec to Minnesota and southward to Florida and Texas. It is found on rich, deep, moderately moist soil near streams and swamps. In North Carolina it is nowhere common, occurring chiefly west of the fall line but in part across the Coastal Plain in the valleys of Roanoke and Cape Fear rivers.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Hicoria aquatica (Michaux son) Britton

Plate XLVI, Figure 5

Salix sp. Berry, Jour. Geology, vol. 15, p. 340, 1907.
Hicoria sp. cf. *H. microcarpa* (Nuttall) Britton. Berry, Idem.
Hicoria aquatica Berry, Torreya, vol. 9, p. 71, 1909; vol. 14, pp. 161, 162, 1914.

This species is represented by a single small but characteristic lateral leaflet and several nuts from

[4] Berry, E. W., Washington Acad. Sci. Jour., vol. 14, p. 16, pl. 1, fig. 36, 1924.
[5] Scribner, F. L., U. S. Dept. Agr. Div. Agrostology Bull. 4, p. 38, 1897.

the locality on Neuse River in Wayne County. As the vernacular name water hickory indicates, this is a species that inhabits frequently inundated river swamps. Its range at the present time extends from southeastern Virginia to Florida and Texas, extending up the Mississippi Valley to the mouth of the Ohio but there as well as elsewhere being confined to the Coastal Plain. In North Carolina it occurs chiefly on the peninsula between Albemarle and Pamlico sounds and in Pender and Brunswick counties in the valleys of Northeast Cape Fear and lower Cape Fear rivers.

It indicates what the areal distribution of the Chowan formation along Neuse River shows—namely, that at that stage of the Pleistocene a drowned river valley like that of the present-day lower Cape Fear extended across Lenoir County and halfway across Wayne County.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Family SALICACEAE

Genus POPULUS Linné

Populus? cf. P. heterophylla Linné

Bud scales similar to those of *Populus* but possibly referable to *Fagus*, leaves of which are so common, occur in the collections from the locality on Neuse River in Wayne County. They are exactly like those of *Populus heterophylla* Linné, which at the present time is found in river swamps from Connecticut to Georgia and Louisiana and is not uncommon in such situations in the Coastal Plain region of North Carolina. Because of the absence of leaves of *Populus* in the deposit and the great abundance of leaves of *Fagus* and *Betula*, which have rather similar resinous bud scales, I have queried the generic reference. In examining the recent river deposits of the Coastal Plain rivers of North Carolina I have frequently noticed bud scales of *Fagus* but have not observed those of *Populus*. *Populus* leaves are, however, recorded from the Pleistocene of Maryland and Alabama.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Genus SALIX Linné

Salix bebbianaformis Berry, n. sp.

Plate XLVI, Figure 8

Leaves of rare occurrence, ovate-lanceolate, with pointed apex and base, entire margins, thin texture. Midvein medium in size. Secondaries thin, ascending, about five regularly spaced, camptodrome pairs.

This species appears to be a Pleistocene willow. Its relation to existing species is entirely problematic, and the name given to it indicates merely a resemblance in leaf form without implying any close botanic relationship.

Salix bebbiana Sargent is a moist-soil species, chiefly of stream and swamp margins, of the northern United States and Canada, and if the fossil could be more precisely correlated with this species, it would afford an interesting problem of distribution.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Salix viminalifolia Berry

Plate XLVII, Figures 1–4

Salix viminalifolia Berry, U. S. Nat. Mus. Proc., vol. 48, p. 297, 1915.

This species was named from its resemblance to the osier willow, *Salix viminalis* Linné, a native of Eurasia, not rare in European Pleistocene deposits, commonly cultivated in our Eastern and Middle States, and here and there escaped in wet places. The name can not be taken as indicative of relationship between the living and fossil species, for the position of the latter is uncertain.

The fossil species may be described as follows: Leaves elongated, linear-lanceolate, abruptly acute at the apex and base. Margins usually somewhat undulate, entire in all the specimens seen. Petiole stout, curved, expanded proximad, 6 to 10 millimeters long. Length about 15 centimeters. Maximum width about 1.5 to 2.25 centimeters. Midvein stout, somewhat flexuous. Secondaries thin, numerous, camptodrome.

Occurrence: Chowan formation, right bank of Neuse River, 4½ miles above Seven Springs, Wayne County (common).

Order FAGALES

Family BETULACEAE

Genus BETULA Linné

Betula nigra Linné

Plate XLVII, Figures 8–19

Betula nigra Knowlton, Am. Geologist, vol. 18, p. 371, 1896.
Berry, Jour. Geology, vol. 15, p. 341, 1907; Am. Naturalist, vol. 41, p. 692, pl. 2, figs. 2–4, 1907; vol. 43, p. 435, 1909; Am. Jour. Sci., 4th ser., vol. 29, p. 393, 1910; Torreya, vol. 14, p. 162, 1914.

Characteristic leaves of the black or river birch, of all sizes, are common in the North Carolina Pleistocene. Their permutations in size and outline are shown in the accompanying figures. The species inhabits swamps and river bottoms and, in the existing flora, ranges from Massachusetts to Minnesota and Kansas and southward to Florida and Texas. In North Carolina it is found along streams and swamp borders throughout the Coastal Plain and Piedmont regions.

The genus goes back to Upper Cretaceous time and became much diversified in the early Tertiary. Several existing species made their appearance in the Pleistocene of this country and Eurasia.

Betula nigra has been reported from the Pleistocene of West Virginia, Virginia, Georgia, Alabama, and Mississippi and was evidently a common and widespread type in the country bordering the coast of the Pleistocene sea in southeastern North America.

Occurrence: Chowan formation, right bank of Neuse River, 4½ miles above Seven Springs, Wayne County (abundant leaves and bark fragments); Pamlico formation, Old Mill Landing, Roanoke River, Pitt County (leaves).

Betula pseudofontinalis Berry

Plate XLVIII, Figures 1, 2

Betula pseudofontinalis Berry, Jour. Geology, vol. 15, p. 341, 1907.

Leaves broadly ovate, with a rounded or bluntly pointed apex and a broadly truncated, rounded, entire base. Margins somewhat irregularly serrate or dentate above. Texture subcoriaceous. Petiole long. Midvein stout. Secondaries stout, rather openly and somewhat irregularly spaced, craspedodrome.

This is a somewhat poorly defined form, named from its resemblance to the leaves of the existing western *Betula fontinalis* Sargent, but the name is not intended to imply a direct botanic relationship with that species.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Genus CARPINUS Linné

Carpinus caroliniana Walter

Plate XLVII, Figures 5–7

Carpinus caroliniana Walter. Berry, Jour. Geology, vol. 15, p. 340, 1907; Am. Naturalist, vol. 41, p. 692, vol. 41, p. 692, pl. 1, figs. 8, 9, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 395, 1910.

Carpinus pseudocaroliniana Hollick, Maryland Geol. Survey, Pleistocene, p. 225, pl. 71, fig. 10, 1906.

The hornbeam, or blue beech, was apparently a common member of the Pleistocene forest flora of southeastern North America and has been recorded from the early Pleistocene (Sunderland) of Maryland and from later Pleistocene deposits in North Carolina, Georgia, and Alabama. In North Carolina it is represented by a small number of characteristic leaves.

In the existing flora it grows in moist woods in the vicinity of streams and swamps and ranges from Nova Scotia westward to Georgian Bay and Minnesota and southward to Florida and Texas, reappearing in the uplands of southern Mexico and Central America. In North Carolina it occurs along streams and in wet situations throughout the State.

There are about a dozen living species in central and southern Europe, Asia, and eastern North America. The genus appears in the Eocene and is exceedingly common in the holarctic Tertiary floras.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Family FAGACEAE

Genus FAGUS Linné

Fagus americana Sweet

Plate XLVIII, Figures 3–13

Fagus ferruginea Aiton. Knowlton, Am. Geologist, vol. 18, p. 371, 1896.
Mercer, Acad. Nat Sci. Philadelphia Jour., 2d ser., vol. 11, pp. 277, 281, figs. 8–15, 1899.
Emerson, U. S. Geol. Survey Bull. 597, p. 148, 1917.

Fagus americana Sweet. Berry, Torreya, vol. 6, p. 88, 1906.
Hollick, Maryland Geol. Survey, Pleistocene, p. 226, 1906.
Berry, Jour. Geology, vol. 15, p. 341, 1907; Am. Naturalist, vol. 41, p. 692, pl. 2, fig. 7, 1907; vol. 43, p. 435, 1909; Am. Jour. Sci., 4th ser., vol. 29, p. 393, 1910; Torreya, vol. 14, p. 162, 1914; vol. 15, p. 206, 1915.

The American beech, sometimes named *Fagus grandifolia* Ehrhart, on the ground of priority, is one of the commonest members of the Pleistocene flora in southeastern North America.

Leaves, nuts, or husks have been recorded from rather numerous localities in Massachusetts, Pennsylvania, Maryland, Virginia, Alabama, and Mississippi. In the North Carolina Pleistocene both leaves and husks are common. The leaves show considerable variation in size and outline, as shown by the accompanying illustrations. In general they appear to have been smaller than the average size of the modern leaves of this species.

In the existing flora the beech occurs chiefly in deep, damp woods, ranging from Nova Scotia to Lake Huron and southward to Florida and Texas. In North Carolina it occurs throughout the State and is said by Pinchot and Ashe to be smaller and less abundant in the Coastal Plain than in the Piedmont and mountain regions.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Genus QUERCUS Linné

Quercus alba Linné

Plate L, Figures 1–5

Quercus alba Linné. Penhallow, Roy. Soc. Canada Trans., vol. 10, sec. 4, p. 74, 1904; Am. Naturalist, vol. 41, p. 448, 1907.
Mercer, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 11, p. 281, 1899.
Berry, Jour. Geology, vol. 15, p. 342, 1907; Am. Jour. Sci., 4th ser., vol. 34, p. 221, 1912.

Quercus pseudoalba Hollick, Maryland Geol. Survey, Pleistocene, p. 227, pl. 70, fig. 2; pl. 71, figs. 1–6, 1906.

The white oak is not uncommon in the Pleistocene, having been recorded from the old Pleistocene (Sunderland) of Maryland, from the interglacial beds of the Don Valley in Ontario, from the Great Valley of Virginia, and from postglacial deposits in Massachusetts. Its leaves, both young and old forms, are common in the Pleistocene of North Carolina.

In the existing flora the white oak is found in woods from Maine to Ontario, westward to Minnesota and Nebraska, and southward to Florida and Texas. In North Carolina it occurs throughout the State but is most abundant on the Piedmont Plateau, being rarely found in the Coastal Plain south of Neuse River or on the latest Pleistocene Pamlico terrace soils of the eastern part of the State.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Quercus abnormalis Berry

Plate LI, Figure 24

Quercus abnormalis Berry, Jour. Geology, vol. 15, p. 342, 1907.

This identification is based upon the single abnormal oak leaf figured. This specimen is incomplete but indicates a linear-lanceolate leaf divided near the middle into two linear-lanceolate lobes that diverge at an angle of about 50°. The margins are entire so far as seen, and the base and tips were probably acute. The midvein is stout and prominent, and numerous stout secondaries diverge from it at wide angles and are camptodrome. The texture is coriaceous, and all the observed features stamp it as a form of *Quercus*, possibly a hybrid or more probably an abnormality. Estimated length about 12 centimeters. Width about 1.5 centimeters.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Quercus predigitata Berry

Plate LIII, Figures 1–6

Quercus falcata Michaux. Knowlton, Am. Geologist, vol. 18, p. 371, 1896.

Quercus predigitata Berry, Jour. Geology, vol. 15, p. 342, 1907; Am. Jour. Sci., 4th ser., vol. 34, p. 22, figs. 4, 5, 1912; Torreya, vol. 14, p. 162, 1914; vol. 19, p. 9, 1919.

This oak is considered to be the ancestral type from which the Spanish oak and the water Spanish oak were differentiated in dry and wet environments. At any rate the fossil leaves show gradations intermediate between the leaves of these modern species, and their precise differentiation in the fossil state is impossible.

The species has a considerable range in the Pleistocene of southeastern North America, being recorded from West Virginia, the Great Valley of Virginia, western Tennessee, and Mississippi. In North Carolina its leaves are common and variable in the deposits of the Chowan formation on Neuse River and are also present in the earlier Wicomico formation near Weldon, both localities near the heads of drowned Pleistocene streams.

The existing *Quercus digitata* Sudworth is a tree of dry soils, ranging from southern New Jersey to central Florida and westward to Texas. In North Carolina it is not uncommon throughout the State except in the western mountains and in the eastern part, which is underlain by the Pamlico formation.

Quercus pagodaefolia Ashe, on the other hand, is a species of rich wet bottom lands and ranges from Virginia to northern Florida and the lower Mississippi Valley. It is common throughout the Coastal Plain in North Carolina.

The recorded range and habitats of the fossil species show clearly that it is either the ancestor of these two species or that the fossil records represent both of these species, which have not been discriminated. It appears not improbable that with the Pleistocene submergence of much of the Coastal Plain and its subsequent emergence *Quercus predigitata* diverged into the two familiar dry and wet soil types.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County. Wicomico formation, 1¼ miles east of Weldon, Northampton County.

Quercus palustris DuRoi

Plate XLIX, Figures 4–6

Quercus palustris DuRoi. Mercer, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 11, pp. 277, 281, fig. 8 [2], 1899.
Berry, Jour. Geology, vol. 15, p. 342, 1907; Torreya, vol. 15, p. 207, 1915.

This species is represented by characteristic leaves in the Chowan formation of North Carolina. It has been previously recorded from the Pleistocene deposits of the cave at Port Kennedy, Pa., where it is represented by a cupule, and the Talbot formation of Maryland.

In the existing flora this species occurs in swamps and wet places from Massachusetts westward to Wisconsin and southward to Florida. It is not uncommon in the Coastal Plain of North Carolina.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Quercus nigra Linné

Plate LI, Figures 1–7

Quercus nigra Linné. Berry, Jour. Geology, vol. 15, p. 342, 1907; Am. Naturalist, vol. 41, p. 693, pl. 1, figs. 3, 4, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 394, 1910; U. S. Geol. Survey Prof. Paper 98, p. 201, pl. 46, fig. 11, 1916.

Quercus marylandica Berry, Jour. Geology, vol. 15, p. 342, 1907.

Leaves of this species are common in the Chowan formation, and some of the larger ones were referred to *Quercus marylandica* in 1907, although it is now believed that all these represent the leaves of the water oak. They show considerable variation in outline and in the tendency toward a trilobate form, as, for example, in the leaf shown in Figure 1; others show an unusual narrowing and elongation of the base, as in Figures 3 and 6.

The oldest deposit in which this species has been found is the Pliocene Citronelle formation of southern Alabama, and its leaves and cupules occur at several Pleistocene localities in Alabama.

In the existing flora it is found on sandy wet soil along streams and swamp borders from southern Delaware southward to Florida and eastern Texas and up the Mississippi Valley to the mouth of the Ohio. In North Carolina it is common throughout the Coastal Plain and in certain areas in the southeastern part of the Piedmont region.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Quercus phellos Linné

Plate LI, Figures 8–23

Quercus phellos Linné. Berry, Jour. Geology, vol. 15, p. 342, 1907; Am. Naturalist, vol. 41, p. 694, pl. 1, fig. 1, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 394, 1910; Torreya, vol. 10, p. 265, 1910; vol. 14, pp. 161, 162, 1914.

The willow oak is not uncommon in the Pleistocene of southeastern North America and has been previously recorded from New Jersey, Alabama, and Mississippi. Both leaves and acorns have been found in the Pleistocene of North Carolina.

The great variety of leaves of this species are partly shown in the accompanying illustrations. None found can be attributed to the water oak, *Quercus laurifolia* Michaux, which might be expected to occur in the North Carolina Pleistocene but which has not been encountered.

In the existing flora *Quercus phellos* is common in low wet situations bordering streams and swamps and to some extent on moist sandy uplands from Long Island to Florida and thence westward to eastern Texas and up the Mississippi Valley to southeastern Missouri. In North Carolina it is exceedingly common in the Coastal Plain and is sparingly present in the Piedmont region.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County (leaves, common); Dupree Landing, Tar River, Pitt County (acorns and cupules).

Quercus prinus Linné

Plate LII, Figures 5–8; Plate LIV, Figure 9

Quercus prinus Linné. Berry, Jour. Geology, vol. 15, p. 342, 1907; Am. Naturalist, vol. 41, p. 693, pl. 1, fig. 1, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 394, 1910; Pan-Am. Geologist, vol. 41, p. 106, 1924.

I am not sure that this species can be distinguished from *Quercus michauxii* by the leaves in the fossil state, but inasmuch as characteristic acorns are associated with the leaves in the Pleistocene of Alabama, I have considered the narrower, longer-petioled leaves of the Pleistocene of North Carolina to represent *Quercus prinus*.

In the existing flora the rock chestnut oak is found in rocky woods from Maine and Ontario to Georgia and Alabama. In North Carolina it is a denizen of dry soils and is found chiefly in the western part of the State, being replaced in the Coastal Plain by the swamp chestnut oak, *Quercus michauxii*, which is also abundant in the Pleistocene forest flora of the State. Inasmuch as there was a crowding together of present-day Coastal Plain and Piedmont types during the Pleistocene epoch, when considerable areas of the Coastal Plain were submerged, and a less clear demarcation between dry and wet soil types, as shown in several localities, the probability is strong that these fossil leaves represent *Quercus prinus*, although this identification can not be said to be absolutely proved. *Quercus prinus* has been recorded from postglacial deposits near Staunton, Va.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Quercus lyrata Walter

Plate L, Figures 6–9

Quercus lyrata Walter. Berry, Jour. Geology, vol. 15, p. 342, 1907.

Characteristic leaves and four flattened acorns of this species, which is not otherwise known in the fossil state, were collected from the North Carolina Pleistocene. It is possible that the acorns from the Port Kennedy cave in Pennsylvania, identified by Stewardson Brown [6] as *Quercus macrocarpa* Michaux, may represent *Quercus lyrata*, as the mossy cup or bur oak is a northern species.

The swamp post oak or overcup oak, *Quercus lyrata*, is found in swampy habitats in the existing flora and ranges from New Jersey and Missouri to Florida and Texas. In North Carolina it is found throughout the Coastal Plain and in the southeastern part of the Piedmont region of the State.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Quercus michauxii Nuttall

Plate LII, Figures 1–4

Quercus michauxii Nuttall. Berry, Torreya, vol. 9, p. 71, 1909; vol. 15, p. 207, 1915.
Quercus prinoides Berry, Jour. Geology, vol. 15, p. 343, 1907.
Quercus platanoides Berry, idem.

Leaves and cupules of this species are found in the Chowan formation of North Carolina, and the species is also recorded from the Talbot formation of Mary-

[6] Mercer, H. C., Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 11, pp. 278, 281, fig. 8, 1899.

land. To it I now refer specimens from North Carolina that were formerly referred to *Quercus prinoides* and *Quercus platanoides*.

The cow oak or swamp chestnut oak is a dweller on moist soils such as swamp borders and river bottoms. In the existing flora it ranges, chiefly in the Coastal Plain, from Delaware to northern Florida and through the Gulf States to Trinity River in Texas and up the Mississippi Valley to southeastern Missouri and the lower Wabash. In North Carolina it occurs abundantly throughout the Coastal Plain and in the swamps of the eastern half of the Piedmont Plateau region.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Quercus velutina Lamarck

Plate XLIX, Figures 1–3

Quercus velutina Lamarck. Penhallow, British Assoc. Adv. Sci. Rept., 1900, p. 336.

Quercus tinctoria Bartram. Penhallow, Roy. Soc. Canada Trans., vol. 10, sec. 4, p. 74, 1904.

This species is represented in the Pleistocene of North Carolina by both leaves and cupules. The only fossil occurrence previously recorded is that in the interglacial deposits of the Dan Valley in Ontario.

In the modern flora this species, which has probably the most variable leaves of all the black oaks, is found on dry soils from Maine and Ontario to Minnesota and Nebraska and southward to northern Florida and central Texas. In North Carolina it is a common tree in the Piedmont and mountain regions but is less abundant in the Coastal Plain.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County. Wicomico formation, 1¼ miles east of Weldon, Northampton County.

Order URTICALES

Family ULMACEAE

Genus ULMUS Linné

Ulmus alata Michaux

Plate LIV, Figures 1, 2

Ulmus alata Michaux. ?Lesquereux, Am. Jour. Sci., 2d ser., vol. 27, p. 365, 1859.

Berry, Jour. Geology, vol. 15, p. 343, 1907; Am. Naturalist, vol. 41, p. 694, pl. 1, figs. 6, 7, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 396, 1910.

Leaves of the wahoo or winged elm are not uncommon in the Chowan formation of North Carolina. This species was recorded many years ago by Lesquereux from the Pleistocene of the Mississippi bluffs near Columbus, Ky., but as there is some question regarding this record it is queried in the above citation. *Ulmus alata* is not uncommon in the Pleistocene of Alabama.

In the existing flora this species occurs in both wet and dry soils from southern Virginia to western Florida and westward to Texas, Missouri, and Arkansas. In North Carolina it is found along streams and swamp margins and is common throughout the State, except in the northwestern part of the Piedmont Plateau and in the mountain region.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Genus CELTIS Linné

Celtis occidentalis Linné

Plate LIV, Figure 3

Celtis occidentalis Linné. Berry, Am. Naturalist, vol. 43, p. 435, 1909.

A single fragment of a leaf of this species was found in the Chowan formation. In the existing flora the species occurs in dry soils from southern Canada southward to Florida and Texas. A stone of this species has been recorded from the Talbot formation of Virginia. Another species is recorded from the Sunderland formation of Maryland, and *Celtis mississippiensis* has been found in the loess of Mississippi. The genus is an old one, not uncommon in the Tertiary of both North and South America.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Genus PLANERA Gmelin

Planera aquatica (Walter) Gmelin

Plate LIV, Figures 4, 5

Planera gmelin Michaux. Lesquereux, Am. Jour. Sci., 2d ser., vol. 27, p. 365, 1859.

Planera aquatica Gmelin. Hollick, Torrey Bot. Club Bull., vol. 19, p. 332, 1892.

Berry, Jour. Geology, vol. 15, p. 343, 1907; U. S. Geol. Survey Prof. Paper 98, p. 201, pl. 47, figs. 1–4, 1916.

Somewhat doubtfully determined leaves of this species occur sparingly in the Chowan formation of North Carolina.

The water elm is one of those interesting relics of a genus otherwise extinct, which attained an extensive distribution during the Tertiary but is now represented by only this single surviving form, which is apparently less wide ranging to-day than it was during Pleistocene time. It appears in the Pliocene Citronelle formation of southern Alabama and in beds of about the same age in southern New Jersey, and it has been found in the Pleistocene of Kentucky and North Carolina.

In the modern flora it is found in more or less inundated swamps and river bottoms from southeastern North Carolina southward in the Coastal Plain to western Florida and westward to Trinity River, Texas, and up the Mississippi Valley to southeastern Missouri and western Kentucky, though usually rare away from the coast. In North Carolina it is found only in the lower valley of Cape Fear River and is no longer present in the valley of Neuse River.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Order PLATANALES

Family PLATANACEAE

Genus PLATANUS Linné

Platanus occidentalis Linné

Plate LV, Figures 1–9

Platanus aceroides Hollick (not Goeppert), Maryland Geol. Survey, Pleistocene, p. 231, pls. 73, 74, 1906.
Platanus occidentalis Linné. Knowlton, Am. Geologist, vol. 18, p. 371, 1896.
Penhallow, Roy. Soc. Canada Trans., 2d ser., vol. 2, sec. 4, pp. 68, 72, 1896; Am. Naturalist, vol. 41, p. 448, 1907.
Mercer, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 11, p. 277, 1899.
Berry, Jour. Geology, vol. 15, p. 344, 1907; Am. Naturalist, vol. 41, p. 695, pl. 2, fig. 5, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 397, 1910; Torreya, vol. 14, p. 161, 1914; vol. 15, p. 207, 1915; Pan-Am. Geologist, vol. 41, p. 106, 1924.
Emerson, U. S. Geol. Survey Bull. 597, p. 148, 1917.

This species is one of the commoner elements of the Pleistocene flora of southeastern North America, being recorded from the oldest Pleistocene of Maryland (Sunderland formation), the interglacial deposits of the Don Valley in Ontario, and postglacial deposits in Massachusetts and Virginia. It is also found fossil in the Talbot formation of Maryland, in the Port Kennedy cave in Pennsylvania, in West Virginia, at various localities in Alabama, and in the Chowan formation of North Carolina, where its leaves are exceedingly common and the flattened fruits or button balls are not rare.

It belongs to an exceedingly interesting genus, which originated in Upper Cretaceous time and represents an order of flowering plants now largely extinct. *Platanus* has many extinct species and attained a holarctic distribution during the Tertiary period. The six or seven surviving species are confined to southwestern Asia and eastern and western North America, with survivors of its once more extended range in the uplands of Mexico and Central America.

The American plane tree or sycamore grows on rich bottom lands from New England to Kansas and Nebraska and southward to Florida and Texas. It is said by Pinchot and Ashe to reach its maximum of size and abundance in North Carolina in the alluvial swamps of the Piedmont Plateau region, but observations show that it is exceedingly common along the Coastal Plain rivers of the State.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Order POLYGONALES

Family POLYGONACEAE

Genus POLYGONUM Linné

Polygonum sp.

An achene, determined by W. L. McAtee as referable to the genus *Polygonum*, is present in the collections from the Neuse River locality in Wayne County. Fossil forms have been recorded from the Pleistocene of Ontario,[7] Maryland,[8] the District of Columbia,[9] and Florida.[10]

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Order RANALES

Family MAGNOLIACEAE

Genus LIRIODENDRON Linné

Liriodendron tulipifera Linné

Plate LIV, Figures 6–8

Liriodendron tulipifera Linné. Berry, Am. Naturalist, vol. 41, p. 695, 1907; Torreya, vol. 9, p. 71, fig. 1, 1909; Am. Jour. Sci., 4th ser., vol. 29, p. 396, 1910; Torreya, vol. 15, p. 208, fig. 1, 1915.

The tulip tree or so-called yellow poplar was another common type in the Pleistocene floras of southeastern North America, where it has been recorded from Maryland, North Carolina, and Alabama, and is represented by both leaves and fruit.

In the existing flora it inhabits deep, rich, moist soil of divides and slopes from Rhode Island to Illinois and southward to Mississippi and northern Florida. In North Carolina it is found throughout the State but reaches its largest size on the slopes of the western mountains.

Liriodendron is another one of those genera of forest trees that have come down to us from the distant past in a greatly diminished way. It was exceedingly abundant and varied during Upper Cretaceous time and attained a holarctic distribution during the Tertiary, which apparently it retained until the close of that period, having been recorded by the Reids [11] from the Pliocene of Holland, and by Schmalhausen [12] from the Pliocene of central Asia. To-day it is restricted to southeastern North America and southern China.

Occurrence: Wicomico formation, 1¼ miles east of Weldon, Northampton County.

---

[7] Coleman, A. P., Geol. Soc. America Bull., vol. 26, p. 247, 1915.
[8] Hollick, Arthur, Maryland Geol. Survey, Pleistocene, p. 231, 1906.
[9] Berry, E. W., Washington Acad. Sci. Jour., vol. 14, p. 19, pl. 1, figs. 19–23, 1924.
[10] Berry, E. W., Jour. Geology, vol. 25, p. 662, 1917.
[11] Reid, C. and E. M., Pliocene flora of the Dutch-Prussian border, p. 93, pl. 8, figs. 1-5, 1915.
[12] Schmalhausen, J., Ueber tertiäre Pflanzen aus dem Thale des Flusses Buchtorma am Fusse des Altaigebirges: Palaeontographica, Band 33, p. 211, pl. 21, figs. 20, 21, 1887.

Order ROSALES

Family HAMAMELIDACEAE

Genus LIQUIDAMBAR Linné

Liquidambar styraciflua Linné

Plate LVI, Figures 9, 10

Liquidambar europaeum Lesquereux (not Alexander Braun), U. S. Nat. Mus. Proc., vol. 11, p. 36, 1888.

Liquidambar styraciflua Linné. Hollick, Torrey Bot. Club Bull., vol. 19, p. 331, 1892.

Knowlton, Am. Geologist, vol. 18, p. 371, 1896.

Berry, Jour. Geology, vol. 15, p. 343, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 397, 1910.

The sweet or red gum is another of our forest trees that was common during the Pleistocene epoch in southeastern North America, when it was scarcely if at all distinguishable in its foliar characters from its wide-ranging Tertiary ancestors. Its oldest occurrence in this region is in the Pliocene of southern New Jersey. It has been recorded from Pleistocene deposits in West Virginia, North Carolina, and Alabama, and in the last two States it is represented by both leaves and fruits.

In the existing flora it grows on the wet soils of bottom lands, ranging from Connecticut to southeastern Missouri, Florida, and eastern Texas. It is essentially a Coastal Plain species, although it reappears in southern Mexico and the uplands of Guatemala, showing that it existed before the development of the wide belt of arid country in southwestern Texas and central and northern Mexico which now divides its once continuous range. It gives to the woods of the South Atlantic States an autumnal brilliancy that is unsurpassed by that of the red maple of the Middle and North Atlantic States.

In North Carolina the sweet gum is found throughout the area east of the mountains but is most abundant and of largest size in the Coastal Plain.

The leaves decay readily, in my experience much more rapidly than those of most of our other forest trees, but the fruits or gum balls are more resistant and are frequently found in the fossil state. The genus goes back at least as far as the Eocene, and it attained a holarctic distribution during the Tertiary period. Survivors of this Tertiary dispersal are still living in southeastern North America and southwestern and southeastern Asia.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Family ROSACEAE

Genus RUBUS Linné

Rubus sp.

Plate LVI, Figure 8

Rubus sp. Berry, Jour. Geology, vol. 15, p. 344, 1907.

Prickly twigs, referred to *Rubus* with some hesitation, occur in the Chowan formation of North Carolina. The genus comprises many existing species of herbs, shrubs, or vines and has a wide geographic distribution. The characteristic seeds of various species have frequently been recorded from Pliocene and Pleistocene deposits in Europe, and doubtless several species were present during Pleistocene time in southeastern North America, but because of the neglect of this field of research in North America, little is known regarding them. Characteristic seeds were recently discovered in abundance in the Wicomico formation of the District of Columbia.[13]

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Family POMACEAE

Genus MALUS Hall

Malus coronariafolia Berry

Plate LVI, Figure 3

Malus coronariafolia Berry, Jour. Geology, vol. 15, p. 344, 1907.

Leaves triangularly ovate, widest below the middle, narrowing to the acute apex. Base broadly rounded, toothed. Length about 4 centimeters. Maximum width about 3 centimeters. Margins with four or five incised lobes on each side, which are finely salient-serrate. Midvein relatively slender. Secondaries about four pairs, slender, ascending; they diverge from the midvein at angles ranging from 45° in the basal pair to half this amount in the distal pair; they are rather straight in their courses and craspedodrome, terminating at the acute tips of the lateral lobes. Tertiaries obsolete.

This species appears to be referable to the genus *Malus*, and its resemblance to the leaves of the existing American crab apple, *Malus coronaria* (Linné) Miller, has suggested the specific name proposed. The latter is a species of moist glades which ranges from Ontario to Potomac River and southward along the Alleghany Mountains to central Alabama. I am not at all sure that the resemblance between the fossil form and this recent species can be considered as an indication of close relationship.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Malus pseudoangustifolia Berry, n. sp.

Plate LVI, Figures 1, 2

Leaves small, somewhat variable in outline, generally ovate, ranging from 2.75 to 4 centimeters in length and 1.25 to 2 centimeters in maximum width, which is usually below the middle. Midvein stout below, becoming thin distad. Secondaries immersed. Apex acute. Base rounded. Margins with rather prominent dentate teeth.

[13] Berry, E. W., Washington Acad. Sci. Jour., vol. 14, p. 20, pl. 2, fig. 1, 1924.

This is a form of somewhat uncertain botanical affinity, named from its resemblance to the existing *Malus angustifolia*, a Coastal Plain species ranging from Pennsylvania to northern Florida and westward to Louisiana. The resemblance is not exact, and it is possible that the fossil may represent some Pleistocene species of *Crataegus*.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Genus CRATAEGUS Linné

Crataegus spathulatoides Berry

Plate LVI, Figure 4

Crataegus spathulatoides Berry, Jour. Geology, vol. 15, p. 344, 1907.

Leaves relatively small, obovate to spatulate. Apex acute to rounded. Base gradually narrowed and acuminate. Margins rather coarsely crenate above the middle. Length about 4 centimeters. Maximum width about 1.5 centimeters. Petiole short and stout. Midvein stout. Secondaries relatively stout; a few ascending pairs diverge from the midvein at acute angles and are camptodrome.

This form is very similar to the leaves of the existing small-fruited haw, *Crataegus spathulata* Michaux, and probably represents that species. Because of the subjective features on which many of the host of recently described species of hawthorn are based, it has seemed likely to be less confusing to give the fossil a new name which shall suggest its resemblance to *Crataegus spathulata*. The latter is a small tree found in rich moist soils, usually stream banks or swamp borders, in the Coastal Plain from southern Virginia to northern Florida and eastern Texas.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Crataegus coccineafolia Berry

Plate LVI, Figures 5–7

Crataegus coccineafolia Berry, Jour. Geology, vol. 15, p. 345, 1907.

This species is based upon leaves and associated thorns. The leaves are relatively small, ovate in general outline, widest medianly, tapering upward to the acute tip and downward to the narrowly cuneate or slightly decurrent base. Margins incised to form two or three triangularly acute lobations on each side, with prominent serrate teeth, which die out in the cuneate base. Length about 3.75 centimeters. Maximum width about 2.25 centimeters. Petiole not preserved. Midvein slender, curved. Secondaries thin, three or four pairs, diverging from the midvein at acute angles, rather straightly ascending, craspedodrome. The thorns, attached to broken pieces of branches, range from 1 to 3.5 centimeters in length and are stout, conically tapering, acutely pointed, and often slightly curved distad.

Both leaves and thorns are practically identical with the corresponding parts of the existing scarlet thorn and certainly represent it or something closely related to it. In view of the maze of existing species into which the thorns have been segregated it has not been deemed profitable to attempt too close correlations between them and the fossil species, as many southern species have very similar foliar characters.

The scarlet thorn is a small bushy tree of rich, well-drained soils and a northern distribution. It ranges from Newfoundland to Connecticut near the coast and up the valley of the St. Lawrence to western Quebec and hence is remote from North Carolina. Could the identity between this existing species and the fossil species be established with certainty the fossil would constitute a conspicuous exotic element in the flora of the Pleistocene of North Carolina and might be considered indicative of a considerable climatic contrast between the North Carolina of Pleistocene time and that of to-day. As such a contrast is not borne out by the associated fossil plants and as many so-called modern species of *Crataegus* have similar leaves and thorns, no dependence can be placed on the resemblances pointed out above.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Family CAESALPINIACEAE

Genus CERCIS Linné

Cercis canadensis Linné

Plate LVII, Figures 10, 11

Cercis canadensis Linné. Penhallow, Am. Naturalist, vol. 41, p. 446, 1907. Berry, Torreya, vol. 11, p. 72, fig. 2, 1909.

Fossil leaves of the redbud or Judas tree have been found in the interglacial deposits of the Don Valley in Ontario and in North Carolina.

In the modern flora this species is said by Sargent, Britton, and Small to range northward as far as southern Ontario, whereas Sudworth gives its normal northern range as the lower valley of the Delaware and southern Michigan. Thence it ranges westward to Nebraska and southward to Florida, Texas, and the Sierra Madre of Nuevo Leon. In North Carolina it is found in both the Piedmont and Coastal Plain regions. It is essentially a warm temperate type, reaching its largest size along Sabine River and having many tropical relatives.

The genus goes back to Eocene time and is represented by existing species in Europe and Asia, as well as in both eastern and western North America. The south European *Cercis siliquastrum* Linné, like its relative in southeastern North America, is represented in the Pleistocene.

Occurrence: Wicomico formation, 1¼ miles east of Weldon, Northampton County.

Order SAPINDALES

Family ILICACEAE

Genus ILEX Linné

Ilex opaca Aiton

Plate LVI, Figures 11, 12

Ilex opaca Aiton. Hollick, Torrey Bot. Club Bull., vol. 19, p. 331, 1892.

Berry, Jour. Geology, vol. 15, p. 345, 1907; Am. Naturalist, vol. 41, p. 696, pl. 2, fig. 1, 1907; Washington Acad. Sci. Jour., vol. 14, p. 21, pl. 2, figs. 4, 5, 1924.

The holly, represented by both leaves and characteristic seeds, has been recorded from the Wicomico formation of the District of Columbia, the Chowan formation of North Carolina, and beds at a corresponding horizon of the Pleistocene in Alabama, the coriaceous spinous leaves being well suited for preservation. In the modern flora it is found in drier situations toward its northern limits, but to the south it occurs chiefly in rich moist soil of woods and bottoms. It ranges from Massachusetts to Florida and Texas. It is common throughout North Carolina except in the mountain region.

The genus *Ilex* goes back to the Upper Cretaceous and contains many extinct species. In the existing flora it comprises very many species, which are widely distributed throughout the world. It is most abundant in Central and South America. Asia also contains numerous species, but there are comparatively few in Europe and Africa.

In addition to *Ilex opaca*, which has been found in the Pliocene of southern New Jersey, several other species of *Ilex* have been recorded from the Pleistocene of southeastern North America, and the genus is also represented in the Pleistocene of Europe.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Order RHAMNALES

Family VITACEAE

Genus VITIS Linné

Vitis sp. Berry

Plate LVII, Figure 6

Vitis sp. Berry, Jour. Geology, vol. 15, p. 345, 1907.

The genus *Vitis* is represented in the Chowan formation by the tendril figured, which is almost certainly that of some grape. It is strange that seeds have not been discovered in the Pleistocene of North Carolina, for they are exceedingly abundant in deposits of this age in southeastern North America, where they have been recorded from New Jersey,[14] Maryland,[15] the District of Columbia,[16] and Virginia.[17]

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

[14] Berry, E. W., Torreya, vol. 10, p. 266, 1910.
[15] Hollick, Arthur, Maryland Geol. Survey, Pleistocene, p. 235, 1906.
[16] Berry, E. W., Washington Acad. Sci. Jour., vol. 14, p. 21, pl. 2, figs. 6–9, 1924.
[17] Berry, E. W., Torreya, vol. 6, p. 89, 1906.

Order THYMELEALES

Family LAURACEAE

Genus PERSEA Linné

Persea pubescens (Pursh) Sargent

Plate LVII, Figure 5

Persea pubescens Sargent. Berry, Jour. Geology, vol. 15, p. 345, 1907.

The swamp bay is a slender tree of pine-barren swamps occurring from North Carolina to Mississippi and Florida, near the coast, and unknown in the upper valley of the Neuse, where it was found fossil.

The related red bay, *Persea borbonia* Sprengel, ranges as a larger tree in somewhat similar situations from Virginia to Florida, Arkansas, and Texas and is believed by some botanists to be an older species than *Persea pubescens*. The foliage of the two is much alike, and it is possible that the fossil may represent the former, although it agrees more perfectly with the leaves of the latter. Neither is otherwise known in the fossil state, although *Persea* is an old genus with many extinct species and has been continuously present in southeastern North America since early Eocene time.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Order UMBELLALES

Family CORNACEAE

Genus NYSSA Linné

Nyssa biflora Walter

Plate LVII, Figure 4

Nyssa caroliniana Poiret. Hollick, Torrey Bot. Club Bull., vol. 19, p. 331, 1892.

Nyssa biflora Walter. Hollick, Maryland Geol. Survey, Pleistocene, p. 235, pl. 69, fig. 5, 1906.

Berry, Torreya, vol. 6, p. 90, 1906; Jour. Geology, vol. 15, p. 345, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 398, 1910; Torreya, vol. 10, p. 266, 1910.

This species, which is often confused with the more widely ranging *Nyssa sylvatica* Marsh, is said by Sargent to be restricted to pine-barren ponds near the coast from North Carolina to Louisiana. Britton gives its northern range as New Jersey, and Shreve records it as common in the river swamps of the Eastern Shore of Maryland.

Leaves or stones have been recorded from the Pliocene of New Jersey and from the Pleistocene of New Jersey, Maryland, and Alabama. In North Carolina fragmentary leaves were collected at the Neuse River locality and stones at the Roanoke River locality.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County. Pamlico formation. Old Mill Landing, left bank of Roanoke River 8 miles above Williamston, Bertie County.

Order ERICALES

Family ERICACEAE

Genus XOLISMA Rafinesque

Xolisma ligustrina (Linné) Britton

Plate LVII, Figure 12

Xolisma ligustrina Britton. Hollick, Maryland Geol. Survey, Pleistocene, p. 236, pl. 69, fig. 6, 1906.
Berry, Jour. Geology, vol. 15, p. 346, 1907; Am. Naturalist, vol. 41, p. 696, pl. 2, fig. 6, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 398, 1910.

This species, which was referred by Linné to *Vaccinium* and is a type that paleobotanists usually refer to *Andromeda*, has been recorded from the Talbot formation of Maryland and from the Pleistocene of Alabama.

In the existing flora it is a species that inhabits swamps and hillsides, and it ranges from Canada to Florida and Arkansas. Still other species occur in the South Atlantic and Gulf States.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Genus DENDRIUM Desvaux

Dendrium pleistocenicum Berry

Plate LVII, Figures 1, 2

Dendrium pleistocenicum Berry, Jour. Geology, vol. 15, p. 346, 1907; Am. Naturalist, vol. 43, p. 436, 1909.

Small, narrowly elliptical leaves, with a rounded apex and base and conspicuously undulate margins. Texture conspicuously coriaceous, and the venation consequently more or less obsolete in the smaller specimens. Midvein in the larger leaves thin and curved, giving off numerous thin wide-angled camptodrome secondaries.

Dendrium is a small genus of shrubs of southeastern North America which are known as sand myrtles. *Dendrium buxifolium* (Bergins) Desvaux is found in sandy pine barrens from New Jersey to North Carolina. A second species, *Dendrium hungeri* Small, with larger leaves, is found in the mountains of North and South Carolina. The leaves of *D. hungeri* agree rather well with those of the fossil, which is regarded as the Pleistocene ancestor of these two modern forms and which inhabited the Piedmont Plateau and the part of the Coastal Plain then above sea level. *Dendrium hungeri* represents a modern upland type much like the Pleistocene form, and *Dendrium buxifolium* represents a pine-barren modification with reduced leaves. This same species has been recorded from the Talbot formation of Virginia.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Family VACCINIACEAE

Genus VACCINIUM Linné

Vaccinium corymbosum Linné

Plate LVII, Figures 8, 9

Vaccinium corymbosum Linné. Hollick, Maryland Geol. Survey, Pleistocene, p. 236, pl. 69, figs. 7–9, 1906.
Berry, Jour. Geology, vol. 15, p. 346, 1907; Am. Jour. Sci., 4th ser., vol. 29, p. 398, 1910; Torreya, vol. 17, pp. 161, 162, fig. 2, 1917.

This species has been recorded from the Pleistocene of Maine, Maryland, North Carolina, and Alabama. In the existing flora it is found in meadow swamps and moist woods and ranges from Newfoundland to Minnesota and southward to Florida and Louisiana.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County. Pamlico formation, Old Mill Landing, left bank of Roanoke River, 8 miles above Williamston, Bertie County.

Vaccinium spatulatum Berry

Plate LVII, Figure 3

Vaccinium spatulata Berry, Jour. Geology, vol. 15, p. 346, 1907.

Small obovate to spatulate leaves, widest above the middle, with broadly rounded apex and narrowly cuneate base. Margins entire, somewhat irregular. Texture subcoriaceous. Length about 2.5 centimeters. Maximum width about 1.2 centimeters. Petiole short and stout, only about 1 millimeter long. Secondaries remote, two or three ascending camptodrome pairs. This leaf has the features of *Vaccinium* and appears to represent an extinct form.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Vaccinium arboreum Marsh

Plate LVII, Figure 7

Berberis sp. Berry, Jour. Geology, vol. 15, p. 343, 1907.
Vaccinium arboreum Marshall. Berry, Torreya, vol. 9, p. 73, 1909; Am. Jour. Sci., 4th ser., vol. 29, p. 398, 1910; vol. 34, p. 222, 1912.

A single broken specimen from the Chowan formation of North Carolina, referred originally to *Berberis*, unquestionably represents the sparkleberry. It has subsequently been found fossil in the Pleistocene of Alabama and the Great Valley of Virginia.

In the existing flora *Vaccinium arboreum* is often a small tree of sandy soil, ranging from North Carolina to Kentucky and southward to Florida and Texas. It is sometimes removed from the genus *Vaccinium* and placed in the genus *Batodendron* Nuttall, as by Small.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Order RUBIALES

Family CAPRIFOLIACEAE

Genus VIBURNUM Linné

Viburnum molle Michaux

Viburnum cf. *V. molle* Michaux. Berry, Torreya, vol. 14, p. 160, 1914.

Two stones that appear to be referable to this species were found in the Chowan formation.

In the modern flora *Viburnum molle* ranges from eastern Massachusetts to Florida and Texas near the coast.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

Viburnum nudum Linné?

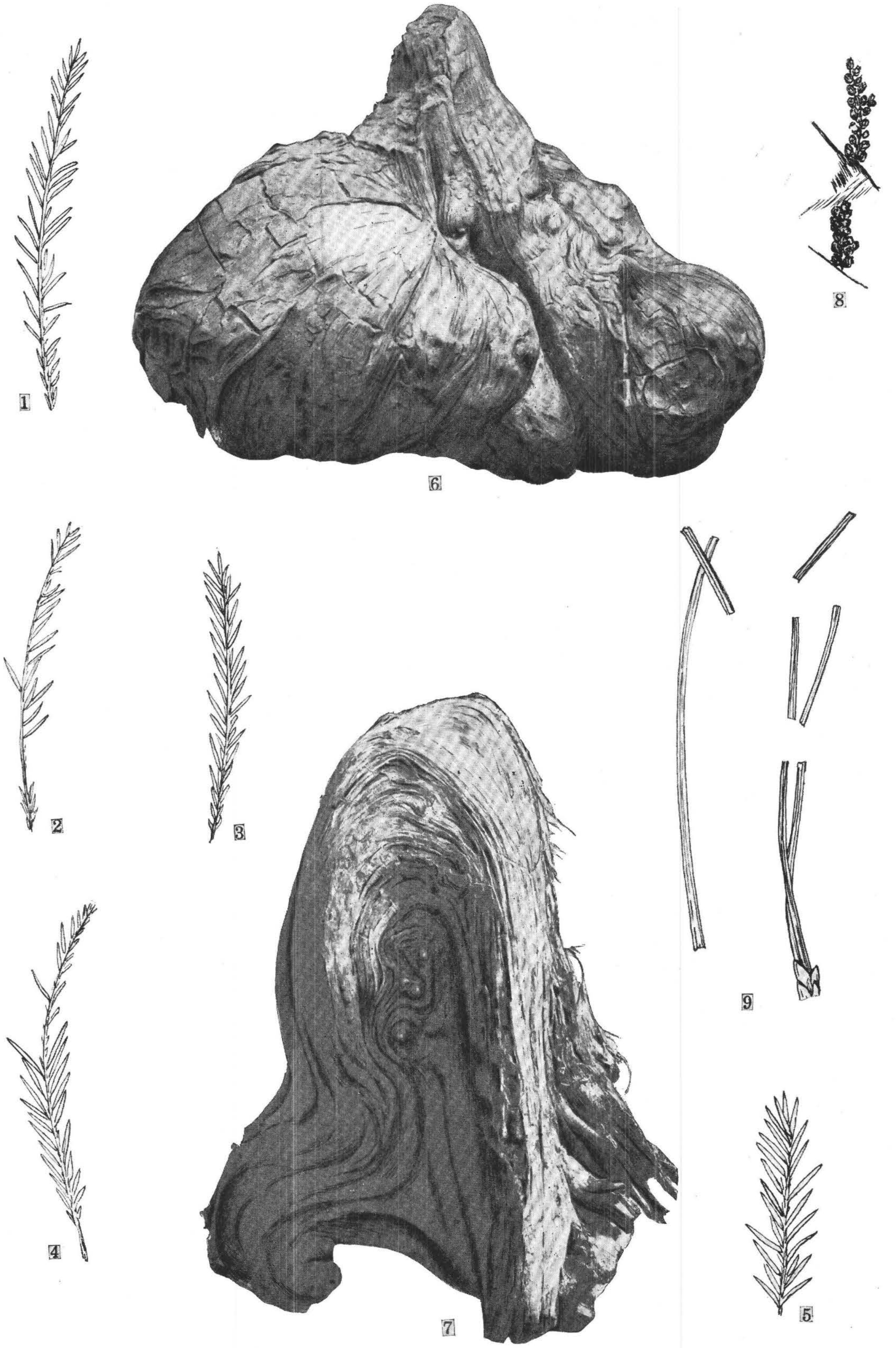
Viburnum nudum Linné. Berry, Torreya, vol. 14, p. 160, 1914; Jour. Geology, vol. 25, p. 662, 1917; Florida Geol. Survey Ninth Ann. Rept., p. 29, 1917; Torreya, vol. 22, p. 11, 1922; Washington Acad. Sci. Jour., vol. 14, p. 23, pl. 2, fig. 25, 1924.

Stones of this species are not uncommon in the Pleistocene of southeastern North America and have been recorded from the Wicomico formation of the District of Columbia, the loess of western Tennessee, and the low-level terrace at Vero, Fla. Two stones that appear to represent this species were collected from the Chowan formation in North Carolina.

In the existing flora it ranges from Long Island to Florida and Louisiana.

Occurrence: Chowan formation, right bank of Neuse River 4½ miles above Seven Springs, Wayne County.

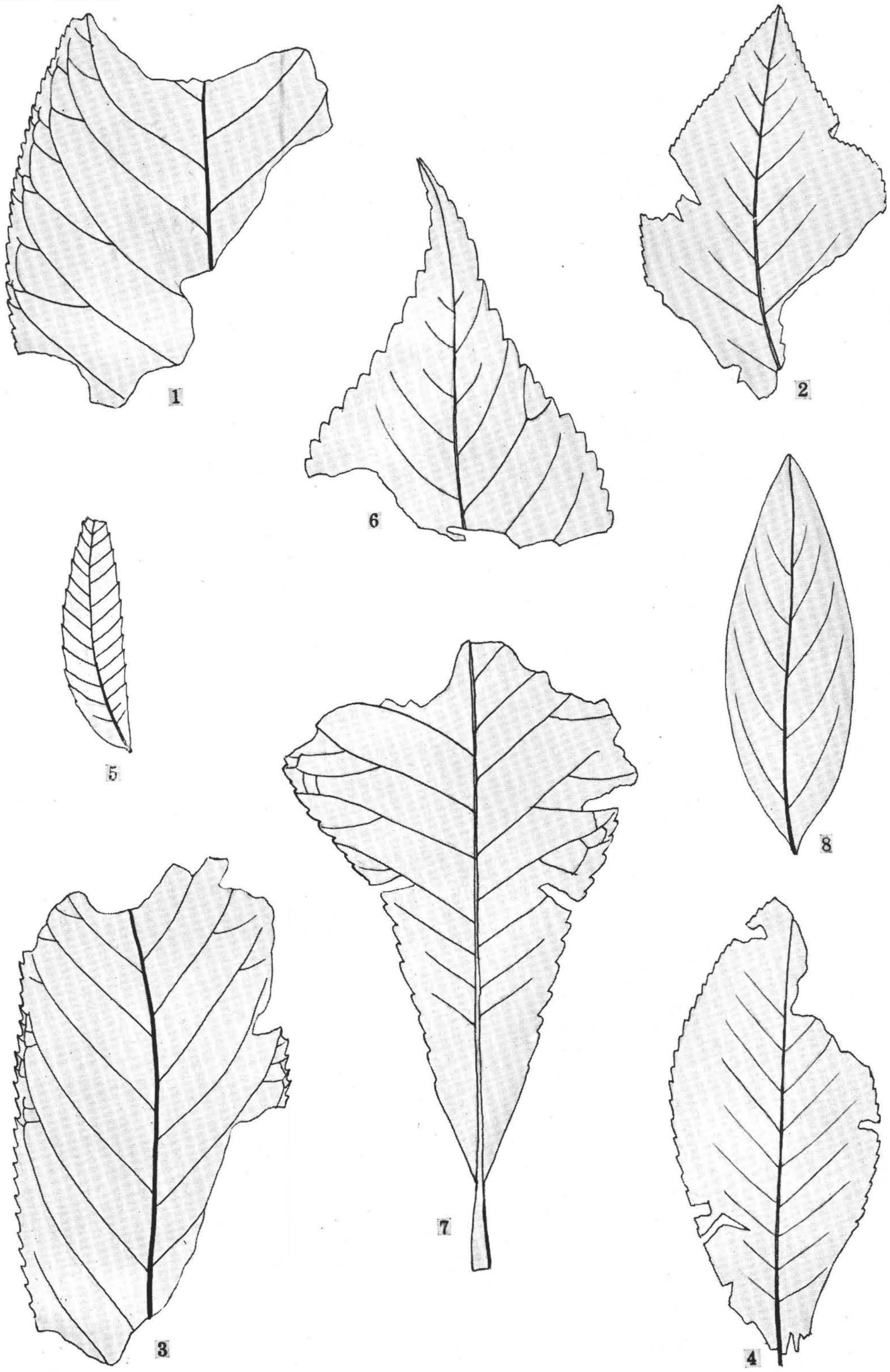
PLATES XLV-LVII



PLEISTOCENE PLANTS FROM NORTH CAROLINA

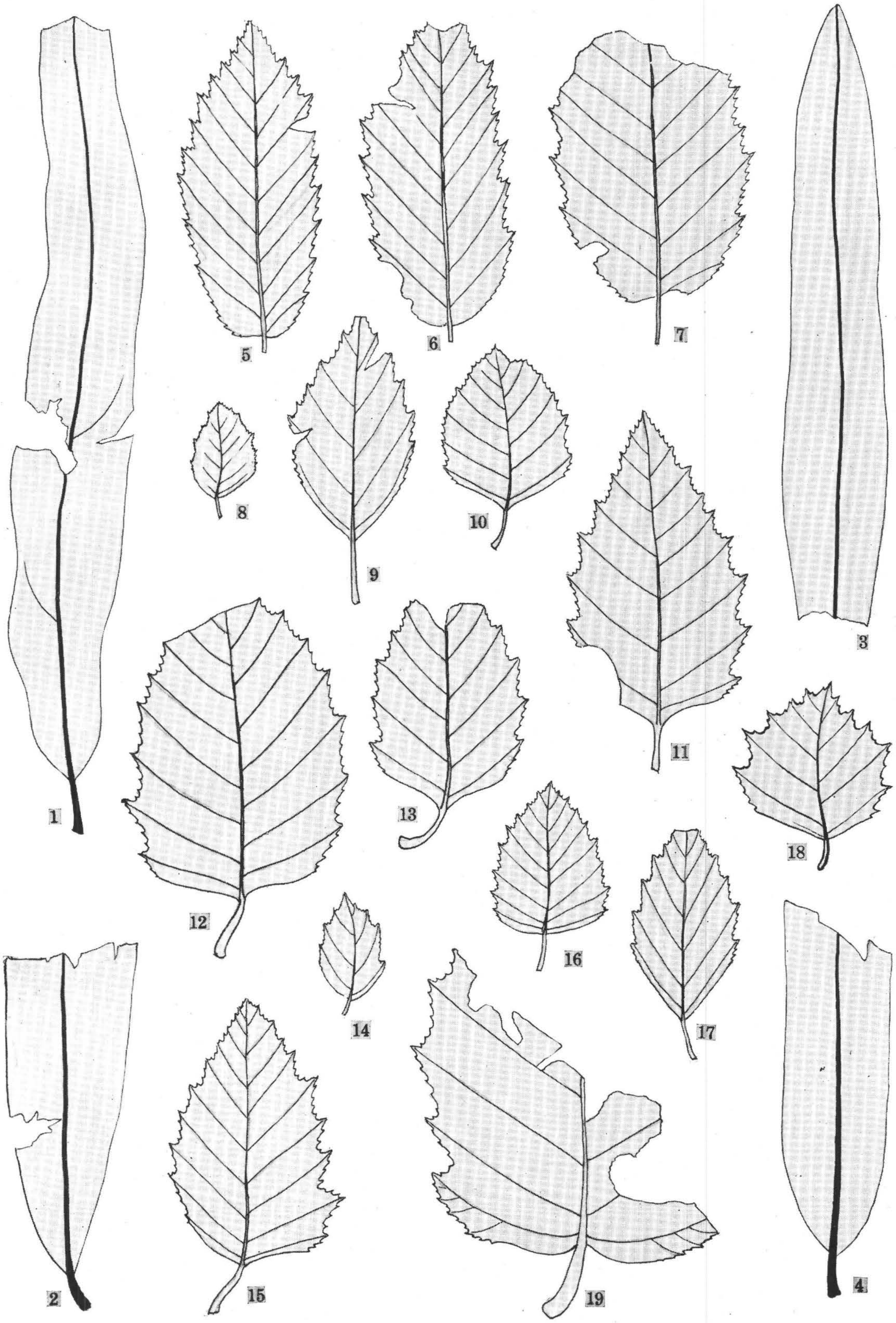
1–8. *Taxodium distichum* (Linné) L. C. Richard (p. 105). (Figs. 6, 7 after Hollick.)
9. *Pinus serotina* Michaux (p. 105).

85658°—26——13



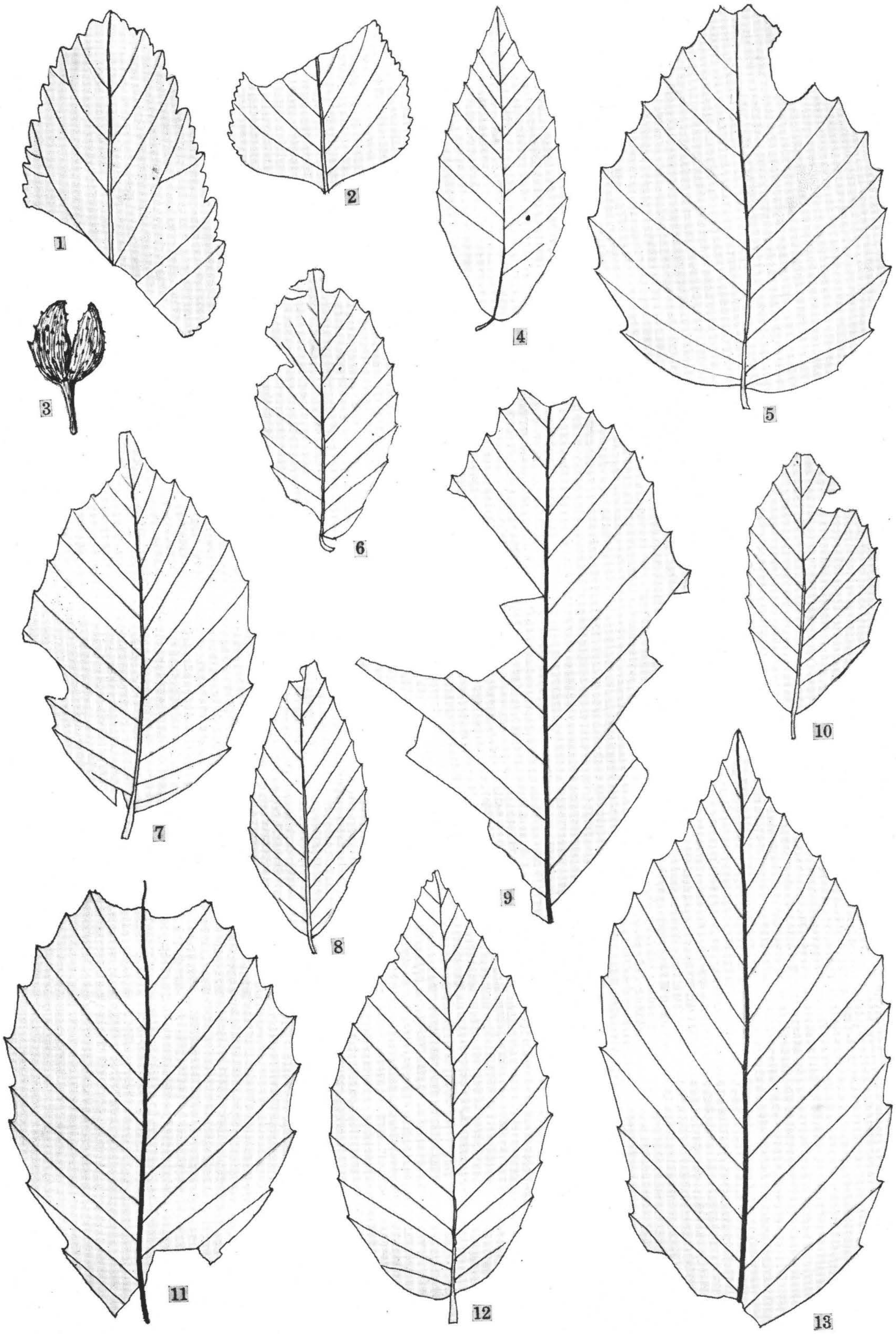
PLEISTOCENE PLANTS FROM NORTH CAROLINA

1–4. *Hicoria glabra* (Miller) Britton (p. 106).
5. *Hicoria aquatica* (Michaux son) Britton (p. 106).
6–7. *Hicoria ovata* (Miller) Britton (p. 106).
8. *Salix bebbianaformis* Berry, n. sp. (p. 107).



PLEISTOCENE PLANTS FROM NORTH CAROLINA

1-4. *Salix viminalifolia* Berry (p. 107).
5-7. *Carpinus caroliniana* Walter (p. 108).
8-19. *Betula nigra* Linné (p. 107).

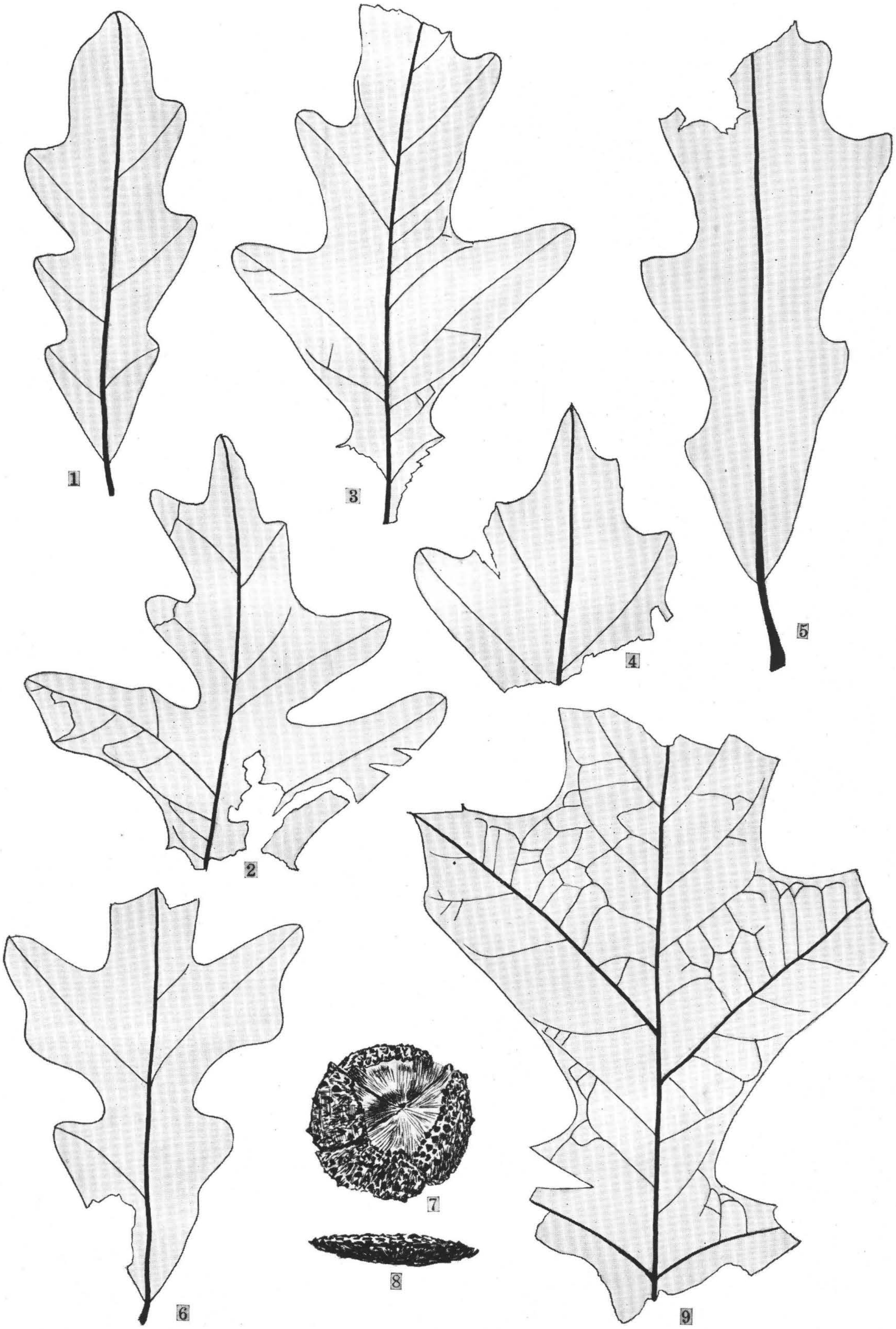


PLEISTOCENE PLANTS FROM NORTH CAROLINA

1-2. *Betula pseudofontinalis* Berry (p. 108).
3-13. *Fagus americana* Sweet (p. 108).

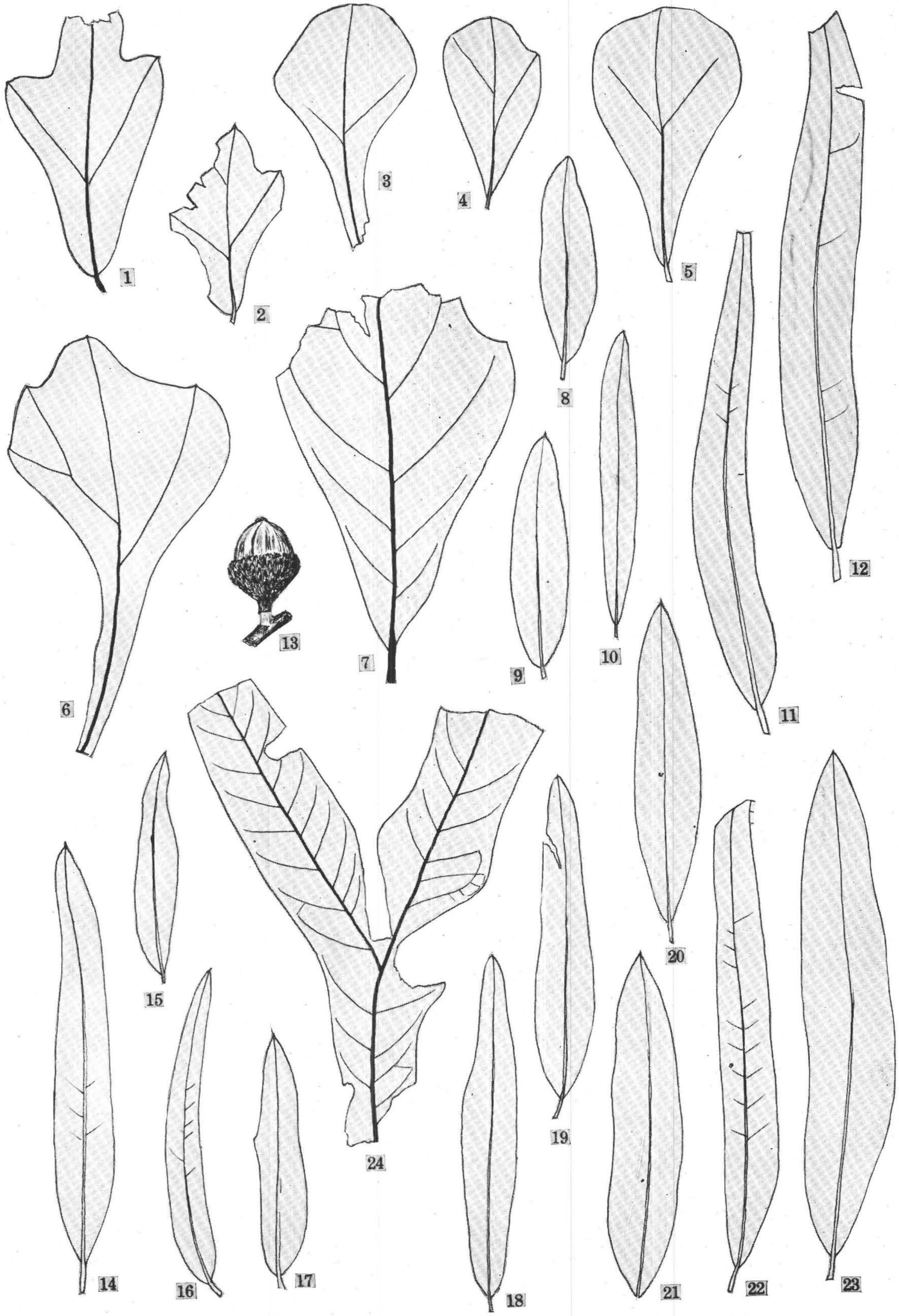
PLEISTOCENE PLANTS FROM NORTH CAROLINA

1-3. *Quercus velutina* Lamarck (p. 111).
4-6. *Quercus palustris* Du Roi (p. 109).



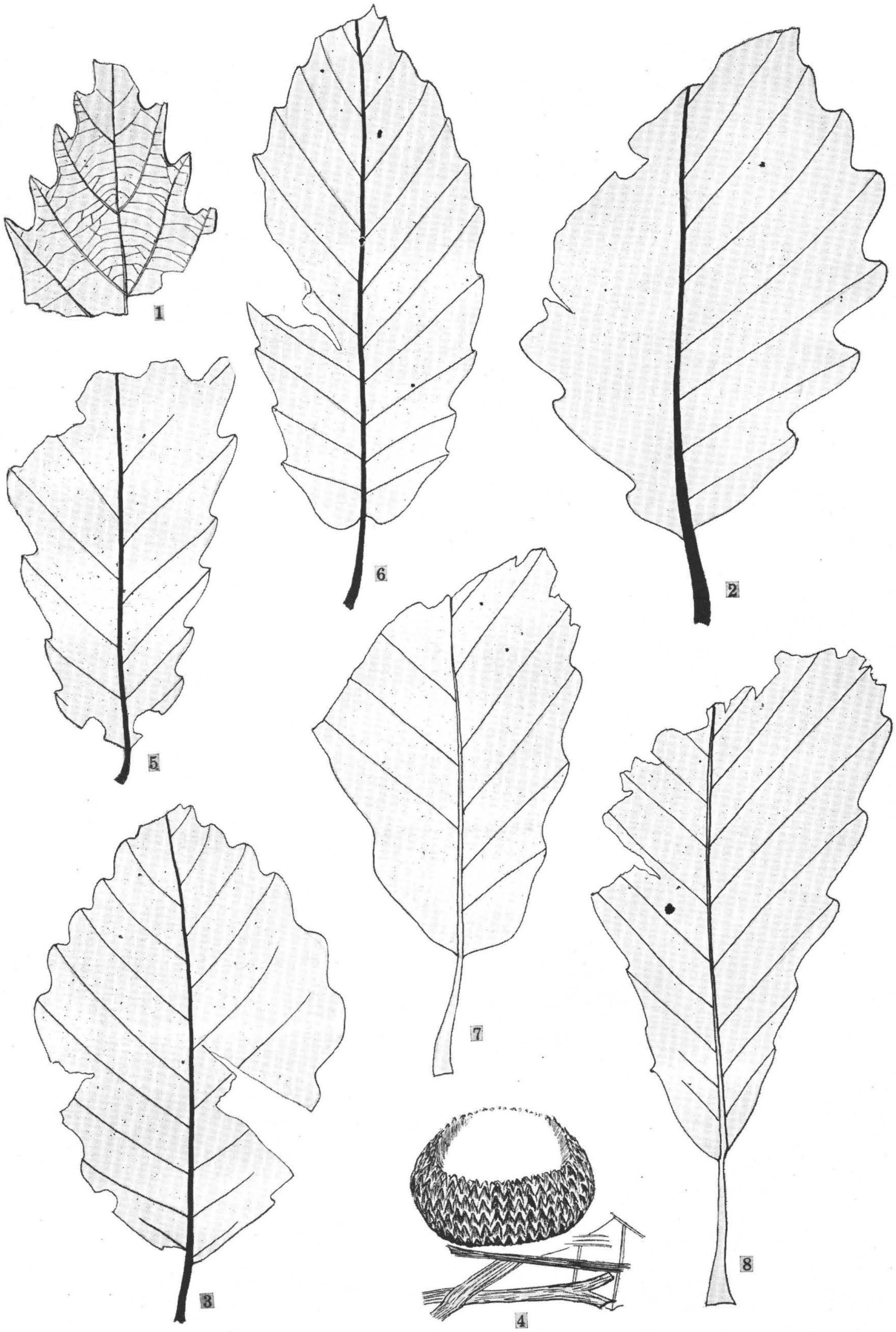
PLEISTOCENE PLANTS FROM NORTH CAROLINA

1–5. *Quercus alba* Linné (p. 108).
6–9. *Quercus lyrata* Walter (p. 110).



PLEISTOCENE PLANTS FROM NORTH CAROLINA

1–7. *Quercus nigra* Linné (p. 109).
8–23. *Quercus phellos* Linné (p. 110).
24. *Quercus abnormalis* Berry (p. 109).

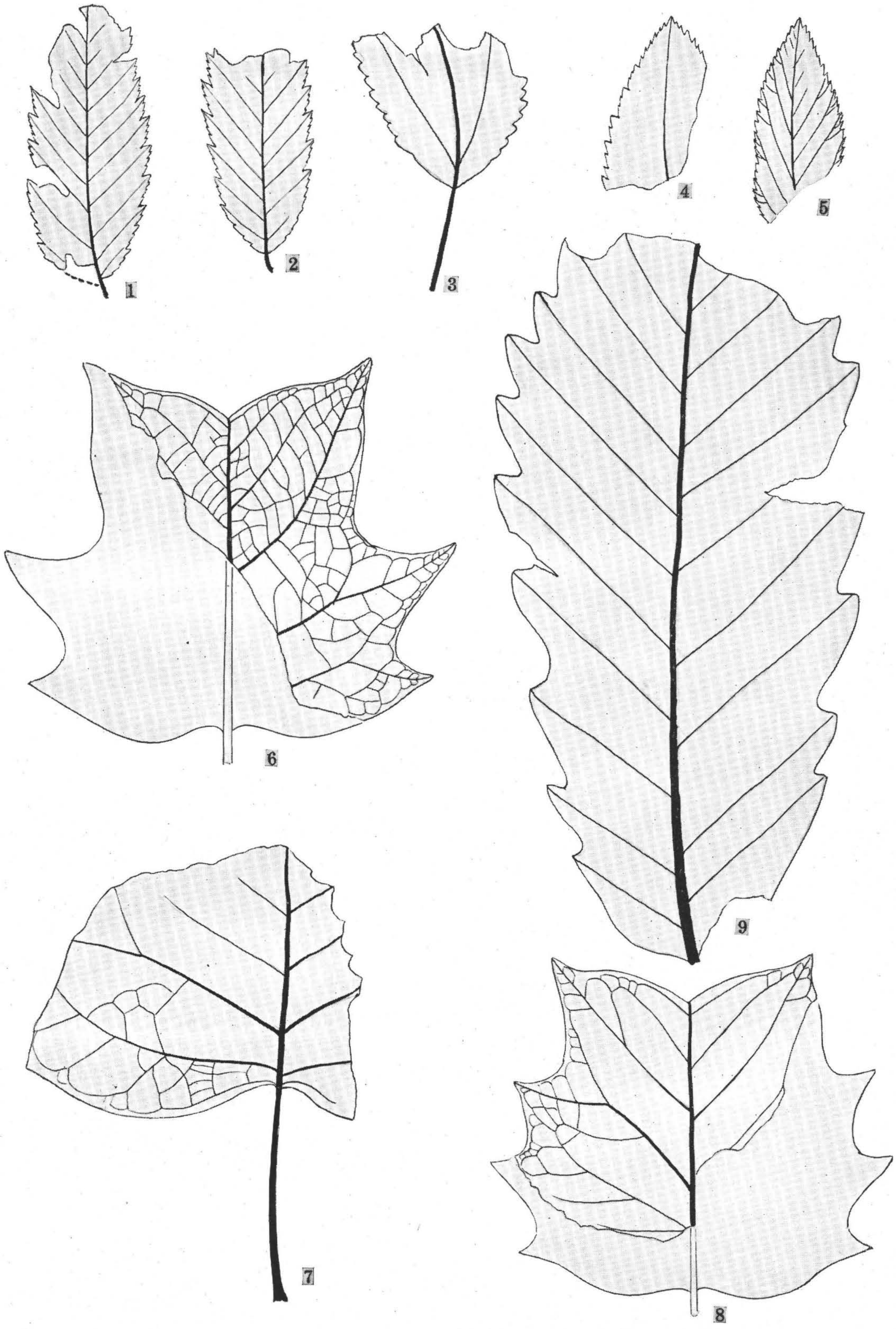


PLEISTOCENE PLANTS FROM NORTH CAROLINA

1-4. *Quercus michauxii* Nuttall (p. 110).
5-8. *Quercus prinus* Linné (p. 110).

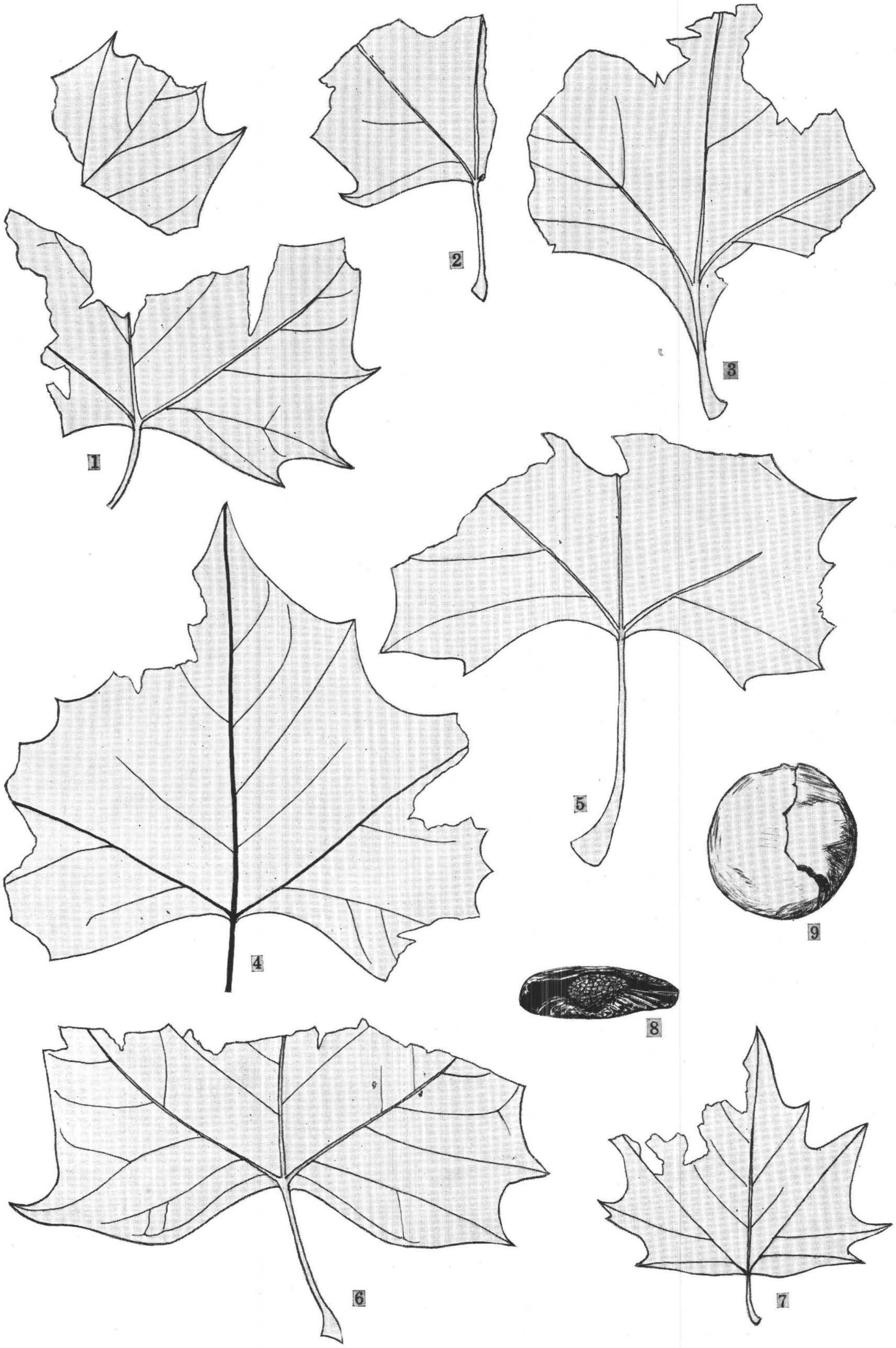
PLEISTOCENE PLANTS FROM NORTH CAROLINA

1–6. *Quercus predigitata* Berry (p. 109).



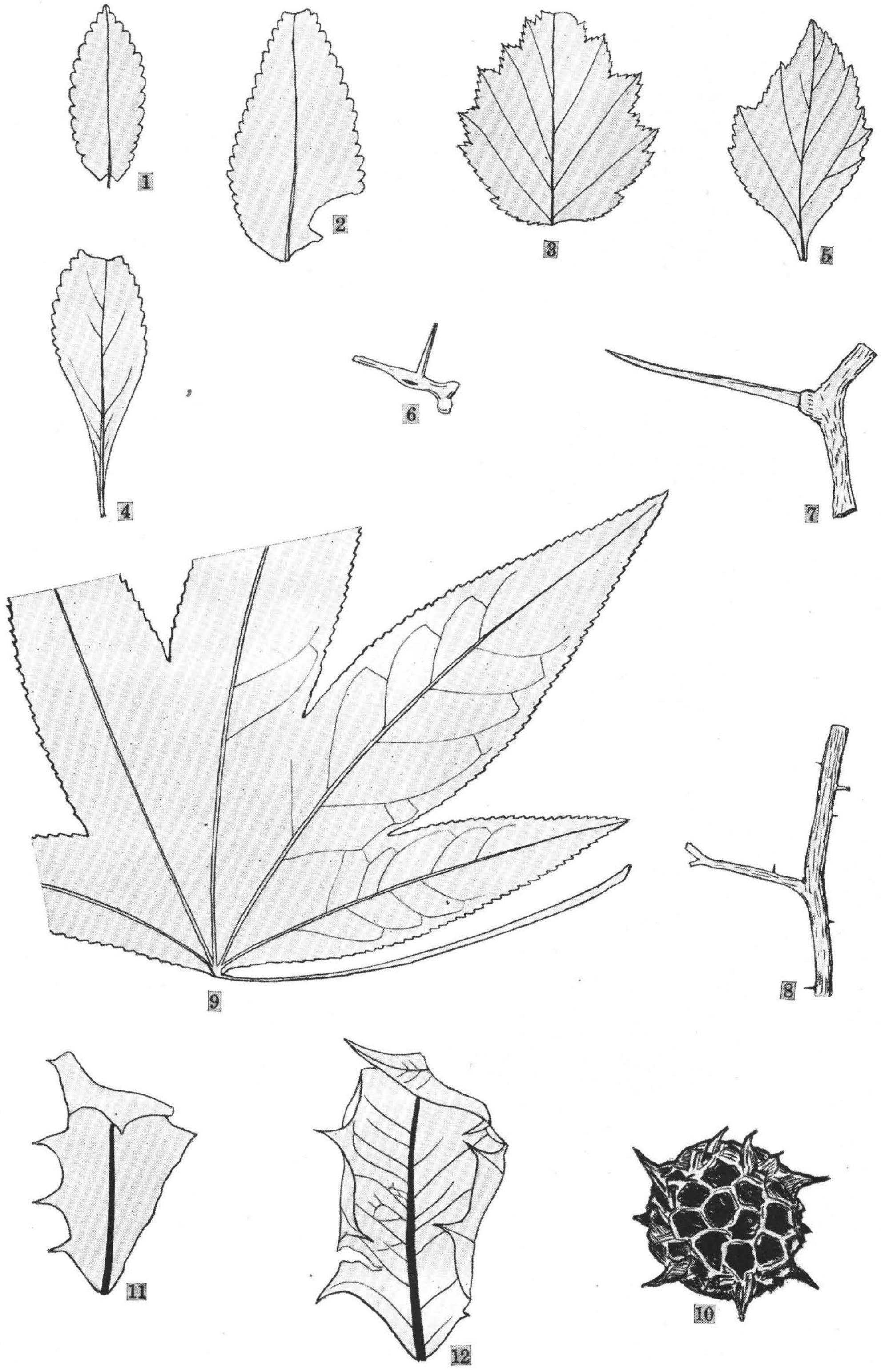
PLEISTOCENE PLANTS FROM NORTH CAROLINA

1-2. *Ulmus alata* Linné (p. 111).
3. *Celtis occidentalis* Linné (p. 111).
4-5. *Planera aquatica* (Walter) Gmelin (p. 111).
6-8. *Liriodendron tulipifera* Linné (p. 112).
9. *Quercus prinus* Linné (p. 110).



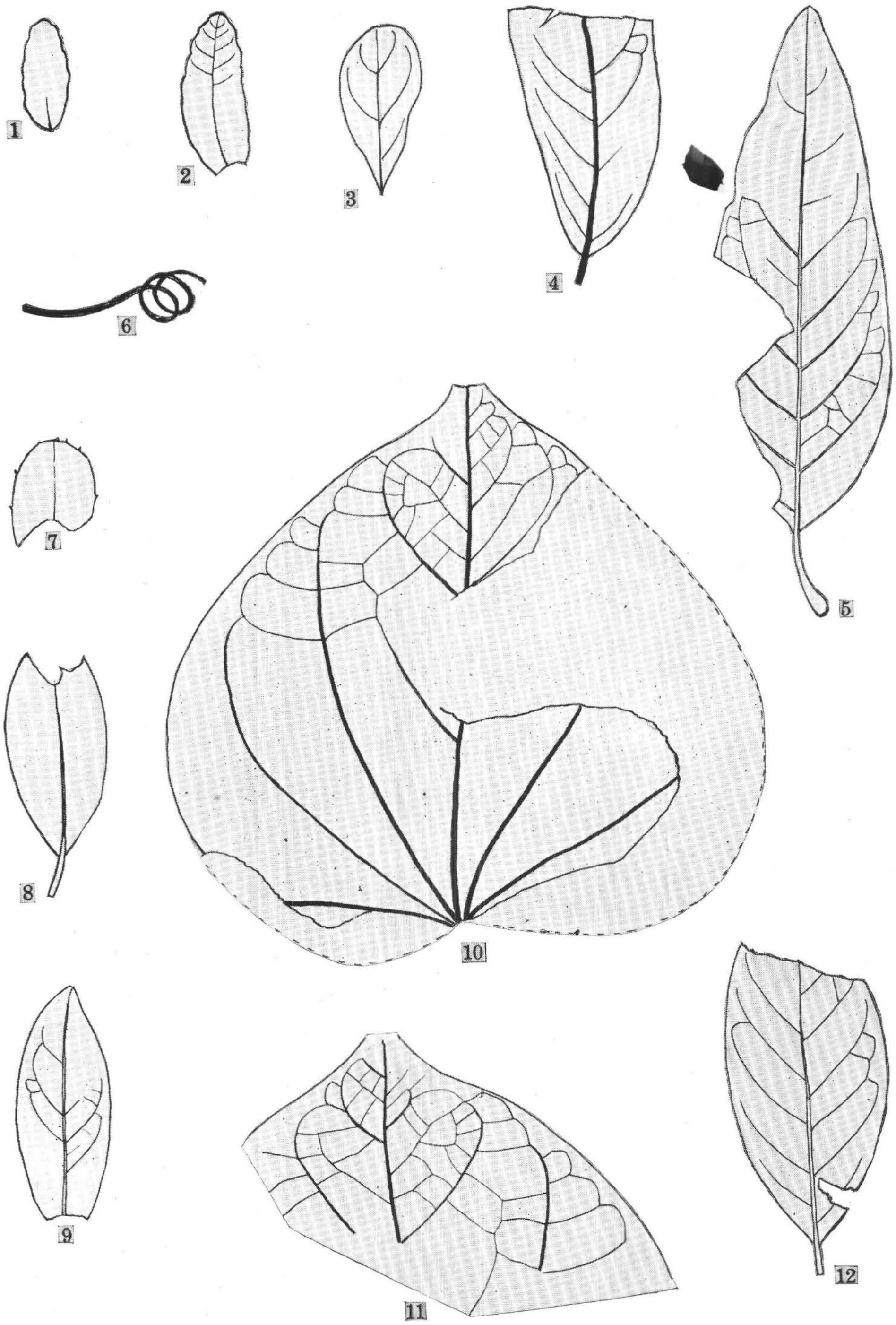
PLEISTOCENE PLANTS FROM NORTH CAROLINA

1-9. *Platanus occidentalis* Linné (p. 112).



PLEISTOCENE PLANTS FROM NORTH CAROLINA

1-2. *Malus pseudoangustifolia* Berry, n. sp. (p. 113).
3. *Malus coronariafolia* Berry (p. 113).
4. *Crataegus spathulatoides* Berry (p. 114).
5-7. *Crataegus coccineafolia* Berry (p. 114).
8. *Rubus* sp. (p. 113).
9-10. *Liquidambar styraciflua* Linné (p. 113).
11-12. *Ilex opaca* Aiton (p. 115).



PLEISTOCENE PLANTS FROM NORTH CAROLINA

1–2. *Dendrium pleistocenicum* Berry (p. 116).
3. *Vaccinium spatulatum* Berry (p. 116).
4. *Nyssa biflora* Walter (p. 115).
5. *Persea pubescens* (Pursh) Sargent (p. 115).
6. *Vitis* sp. Berry (p. 115).
7. *Vaccinium arboreum* Marsh (p. 116).
8–9. *Vaccinium corymbosum* Linné (p. 116).
10–11. *Cercis canadensis* Linné (p. 114).
12. *Xolisma ligustrina* (Linné) Britton (p. 116).

SHORE PHASES OF THE GREEN RIVER FORMATION IN NORTHERN SWEETWATER COUNTY, WYOMING

By Wilmot H. Bradley

INTRODUCTION

PURPOSE AND SCOPE OF THE REPORT

For the last two years the writer has been engaged in a detailed study of the Green River formation and its oil shale. In order to arrive at an intelligent interpretation of this great series of lacustrine beds, the field study has been focused upon the marginal phases of the deposits and the associated formations, to determine, first, so far as possible from the geologic and biologic evidence recorded there, the environmental conditions that prevailed when these beds were laid down, such as the geologic history and physical configuration of the basin of deposition, the mode of filling, the sources and nature of the materials, and the climatic conditions under which the deposits accumulated. From the same evidence the writer has also endeavored to determine the kinds and relative abundance of both plant and animal life that existed in the Green River lake and on the adjacent land. Such evidence is fragmentary, as was to be expected, but it serves well as a basis for further study and interpretation.

The field studies have been supplemented by microscopic study of the oil shale and its microorganisms and of the associated rocks, such as the calcareous alga reefs and oolites. Much valuable information has also been obtained from an investigation of the processes of sedimentation that are taking place in modern inland lakes and the kinds of deposits that are produced by these processes. The interpretation of the organic shale and limestone must depend largely upon evidence of this kind.

This report records the results obtained from a field and office study of shore phases of the Green River formation on the northeastern margin of the Green River Basin and presents a brief summary of the writer's preliminary conclusions regarding the origin of the Green River oil shale.

EARLIER INVESTIGATIONS

The area described in this report is part of the Green River district mapped and studied by F. M. Endlich.[1] In this reconnaissance work the Wasatch, Green River, and Bridger formations were differentiated and mapped. The accuracy of the mapping in part of the area here described was materially increased by the work of Schultz [2] and Smith [3] in 1907 and 1908.

FIELD WORK

In 1923 the writer, assisted by Carle H. Dane, mapped this area and studied particularly the phases of sedimentation in the Green River formation. The mapping was done largely by means of plane tables and telescopic alidades on a system of triangulation extended from a base line measured on a level-topped ridge just north of Steamboat Mountain. Isolated areal features were mapped in part on a topographic base furnished on a few of the General Land Office township plats and in part by means of pace traverses. The mapping was tied to section corners at many points.

The accompanying geologic map (Pl. LVIII) was compiled from the field sheets of Schultz, Smith, and the writer. Data obtained by Schultz and Smith were checked in the field and supplemented by new material. The location of the area is shown in Figure 7.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the assistance of Mr. John W. Hay, of Rock Springs, Wyo., who supplied the party with saddle horses from his ranch, a few miles northeast of the area mapped. He also wishes to thank Mr. Banks W. Brady, of Eden, Wyo., for his cordial hospitality.

TOPOGRAPHY

A belt of shifting sand dunes from 4 to 8 miles wide extends from west to east across the southern part of the area and far out into the Red Desert Basin. Steamboat Mountain (altitude 8,630 feet above sea level) rises about a thousand feet above the general level of these dunes and is flanked on the east by a slightly lower escarpment, which faces southeast and extends northeastward beyond the limits of the area, and on the west by a similar escarpment, which faces southwest and extends northwestward. From these

[1] U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., for 1877, pp. 131–139, pl. 3 (geologic map), 1879; Twelfth Ann. Rept., for 1878, pl. 3 (geologic map), 1883.

[2] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702,, pl. 1, 1920; also unpublished field sheets.

[3] Smith, E. E., unpublished field sheets.

escarpments the country slopes gently to the north. The western part of the area includes a small portion of the Bridger Basin.

Morrow Creek and its tributaries drain the western two-thirds of the area and Alkali Creek the eastern third. The Continental Divide separates these two drainage basins.

STRATIGRAPHY

The exposed rocks in this area belong to the Wasatch, Green River, and Bridger formations. Toward the north a part of the Green River formation is separated from the main body of that formation by a tongue of the Wasatch formation, which comes in from the north. The terms Tipton tongue of the Green River formation and Cathedral Bluffs tongue of the Wasatch formation have been applied to these tongues [4] and will be used in this paper. Plate LIX shows the relations of these tongues to the other members of the Green River and Wasatch formations and to the overlying Bridger formation. Measured sections of the formations are given on pages 129–131.

WASATCH FORMATION

Only the upper 450 feet of the main body of the Wasatch formation is exposed in this area. This upper part consists largely of clay, which is predominantly drab but locally is banded with pink and maroon tints. Cross-bedded or massive lenticular beds of sandstone of stream-channel origin make up the remainder of the upper part.

The Cathedral Bluffs tongue of the Wasatch formation is more heterogeneous. It consists of clay ranging in color from green through greenish gray, gray, and buff to deep red; sandstone; sandy limestone; and locally thin calcareous alga reefs. Additional facts regarding these deposits are given under the heading "Source of sediments." Measured sections of the Cathedral Bluffs deposits are given on page 131.

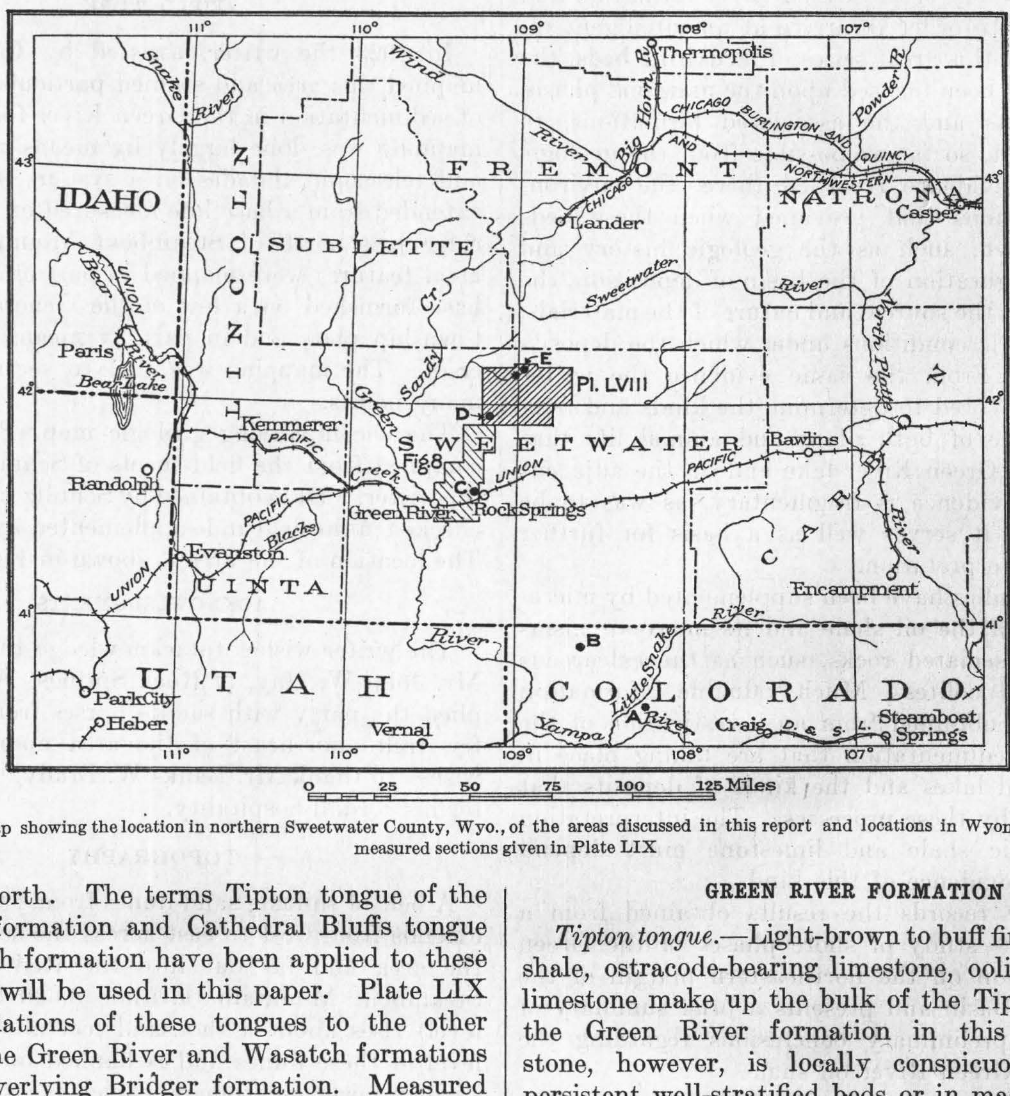
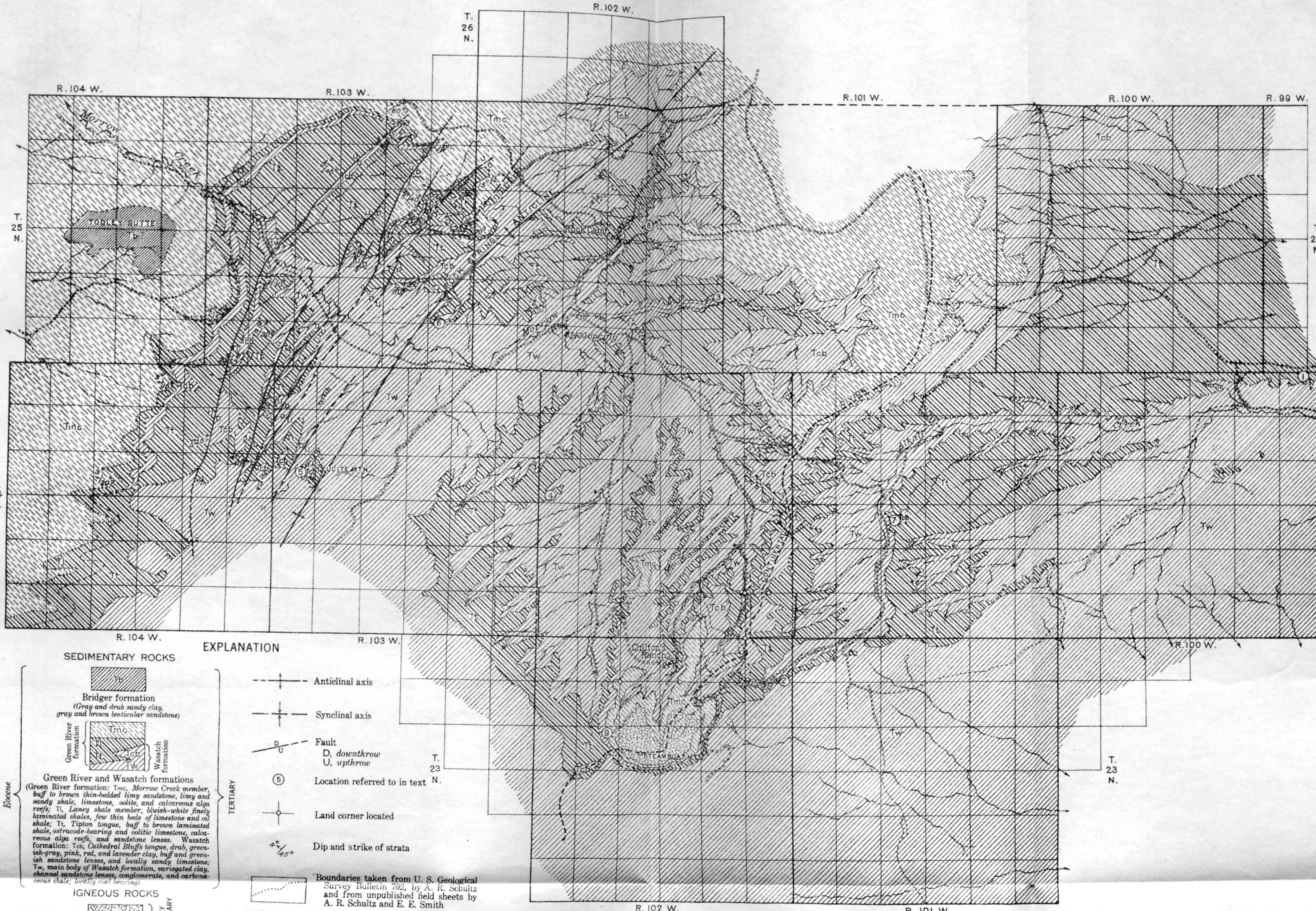


FIGURE 7.—Index map showing the location in northern Sweetwater County, Wyo., of the areas discussed in this report and locations in Wyoming and Colorado of measured sections given in Plate LIX

GREEN RIVER FORMATION

Tipton tongue.—Light-brown to buff finely laminated shale, ostracode-bearing limestone, oolite, and sandy limestone make up the bulk of the Tipton tongue of the Green River formation in this area. Sandstone, however, is locally conspicuous, either in persistent well-stratified beds or in massive or cross-bedded lenses. Calcareous alga reefs are numerous in the Tipton tongue. At the base of the Tipton tongue throughout this area and beyond there is a very persistent limestone in which ostracodes are in places so abundant as to compose most of the rock. In the southwestern part of this area and to the south along White Mountain the Cathedral Bluffs

[4] Sears, J. D., and Bradley, W. H., Relations of the Wasatch and Green River formations in northwestern Colorado and southern Wyoming: U. S. Geol. Survey Prof. Paper 132, pp. 98–99, 1924.



Base compiled from field sheets and land plats of the General Land Office

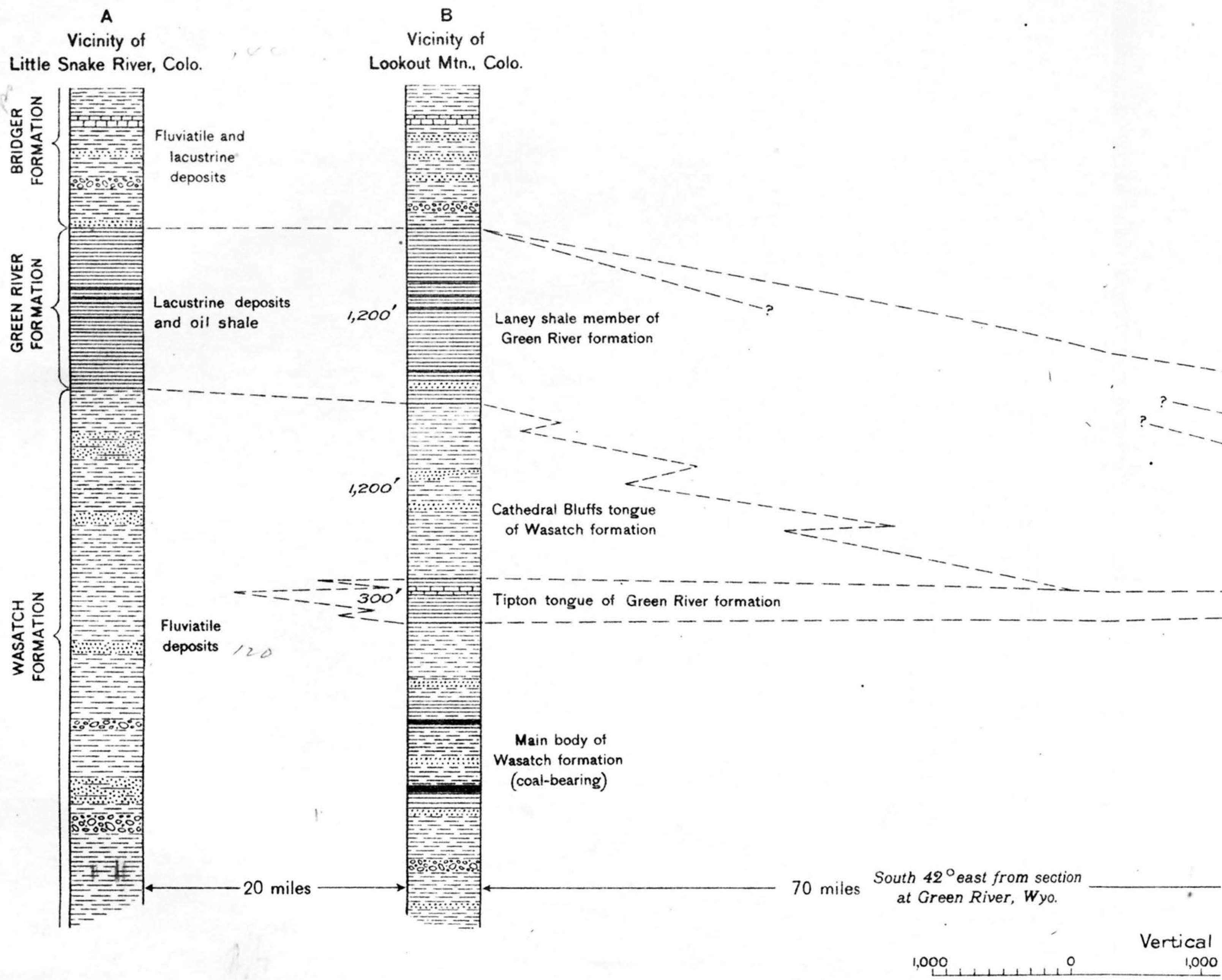
GEOLOGIC MAP OF A PORTION OF NORTHERN SWEETWATER COUNTY, WYOMING

Geology by W. H. Bradley and C. H. Dane
Surveyed in 1923

Scale $\frac{1}{250,000}$

0 1 2 3 4 5 6 MILES

1925



SECTIONS IN THE GREEN RIVER BA

Showing interfingering of Green

tongue of the Wasatch formation is not represented, and the southern continuation of the Tipton beds is more appropriately termed the Tipton shale member of the Green River formation. Additional facts regarding the Tipton deposits are given under the heading "Source of sediments," and measured sections of the deposits are given on pages 129 and 130.

Laney shale member.—In this area and in White Mountain, to the southwest, the deposits overlying the Tipton tongue belong to the Laney shale member, which here consists entirely of finely laminated shale, oil shale, and limestone. The rocks of this member without exception weather bluish white and make a conspicuous feature of the landscape. (See Pl. LX, *A*.) Their relations to the underlying Tipton tongue and the Cathedral Bluffs tongue of the Wasatch formation are shown in Plate LIX. The thickness of the beds is stated under "Source of sediments," and the lithology is further described under "Origin of Green River oil shale."

Tower sandstone lentil and Morrow Creek member.—In this area the Laney shale member thins and disappears completely toward the north and east. The overlying member of the Green River formation, which Powell [5] called the "Upper Green River," continues eastward to Steamboat Mountain and northeastward to Oregon Buttes and Continental Peak, beyond which it was not traced. In Powell's definition of the "Upper Green River" he included a basal sandstone, which he designated the Tower sandstone, and the overlying plant beds. The Tower sandstone was so named because it forms the tops of the weathered rock masses known in the vicinity of Green River as The Towers. (See fig. 8 and Pl. LX, *B*.) It is lenticular and is therefore herein designated the Tower sandstone lentil of the Green River formation. It consists of cross-bedded and massive beds of medium to coarse grained brown sandstone which is firmly indurated by a limonitic cement. The Tower sandstone is not present in the area described in this report but occurs farther south, in the vicinity of the town of Green River, Wyo. In the northern part of Sweetwater County it appears to be replaced by the lower part of the plant-bearing beds herein designated the Morrow Creek member of the Green River formation, because of their extensive exposures in the valley of Morrow Creek. (See Pl. LIX, which illustrates the lenticular nature of the Tower sandstone and its relations to the Morrow Creek member.) The Morrow Creek member is a distinct lithologic unit easily traceable from this area southward along the top of White Mountain to the Union Pacific Railroad and thence westward to Green River. It consists largely of buff sandy limestone and buff sandstone, which contrast rather sharply with the underlying bluish-white Laney shale member. Poor bedding and chippy fragments are characteristic of the exposures of these beds. In addition to the sandstone and limestone there is a small amount of light-brown paper shale and an occasional alga reef or pisolite. Locally plant impressions are abundant. The Morrow Creek member ranges in thickness from 100 to 300 feet. A measured section of it is given on page 131.

[5] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains, p. 45, U. S. Geol. and Geog. Survey Terr., 2d div., 1876.

BRIDGER FORMATION

The Bridger formation occupies but a small portion of this area. It consists of poorly consolidated coarse-grained sandstone and dull-gray sandy clay. These beds weather into pronounced badland forms.

IGNEOUS ROCKS

Steamboat Mountain is capped by two flows of a unique leucite-rich lava called wyomingite. According to Kemp and Knight [6] the rock consists principally of leucite and phlogopite, together with a small amount of diopside and hornblende in a gray-green glass. The accessory minerals are rutile and apatite.

STRUCTURE

The structure of this area is determined by the Rock Springs anticline, the axis of which passes through Leucite Mountain. The anticline plunges rapidly to the northeast and loses its identity just north of this area in a very shallow syncline, which is roughly parallel to the major axis of the Wind River Mountains.

Dips of 1° to 2° NE. prevail east of the anticlinal axis. On the west flank the dips are generally steeper and the rocks are displaced by a zone of nearly parallel normal faults that has the same trend as the anticlinal axis. The faults are marked by rather prominent scarps, a fact which perhaps indicates a recent origin.

SOURCE OF SEDIMENTS

At the base of the Tipton tongue throughout this area and extending beyond the area as far south as Fourteenmile Spring, in sec. 33, T. 21 N., R. 105 W., there is a limestone of a surprisingly persistent nature. It varies in thickness from place to place but is nowhere entirely absent. Most commonly it is oolitic or even pisolitic and always carries a great abundance of ostracodes (Pl. LXI, *B*), locally so many that they form the greater part of the rock. In almost constant association with these features are *Goniobasis* shells and more rarely *Unio* shells.

Above this remarkably persistent basal limestone there is a noticeable differentiation in the lithology of the Tipton tongue in different parts of the area. Southeast of a diagonal line drawn through secs. 1 and 31, T. 24 N., R. 102 W., the Tipton tongue con-

[6] Kemp, J. F., and Knight, W. C., Leucite Hills of Wyoming: Geol. Soc. America Bull, vol. 14, p. 326, 1903.

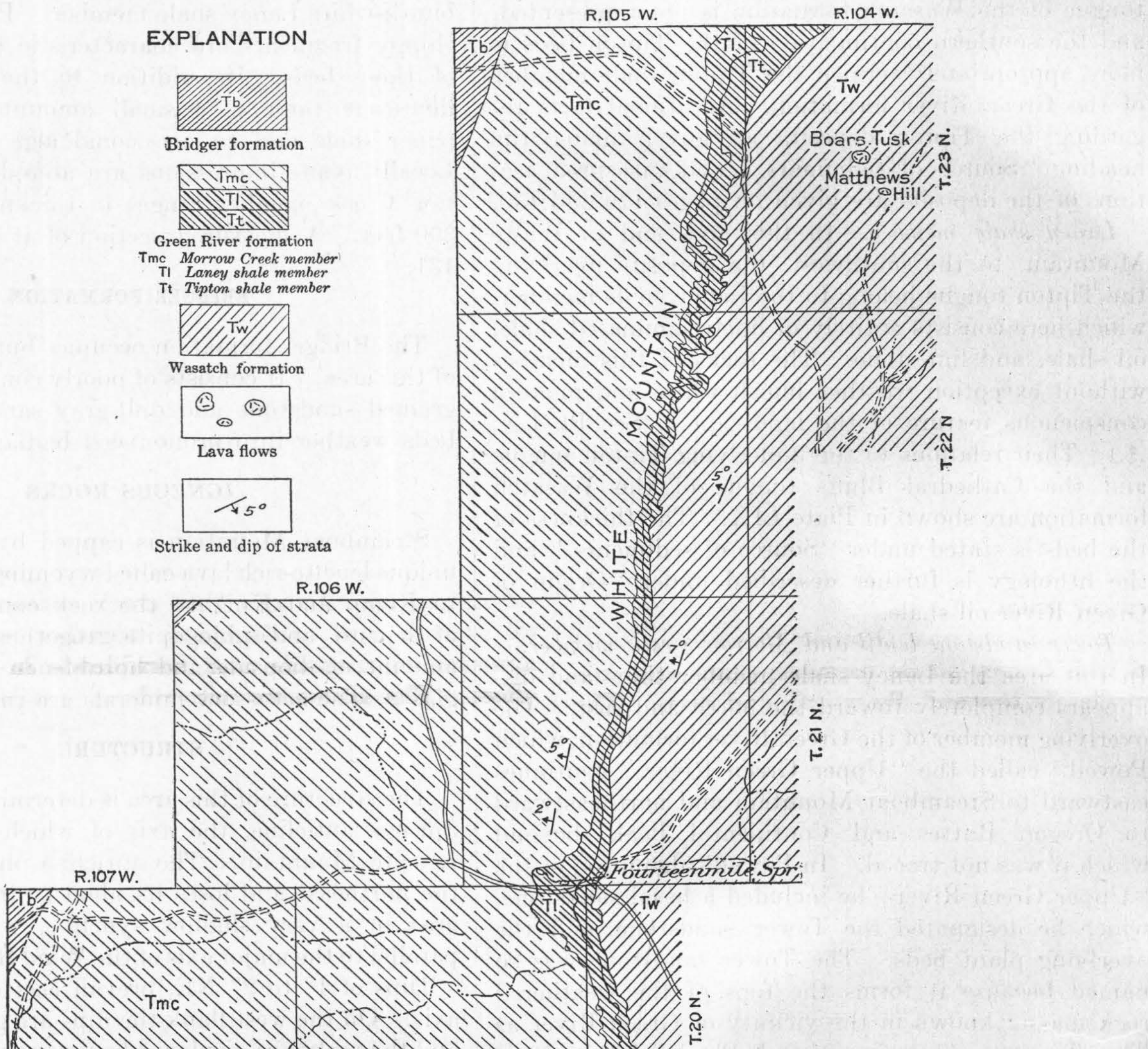
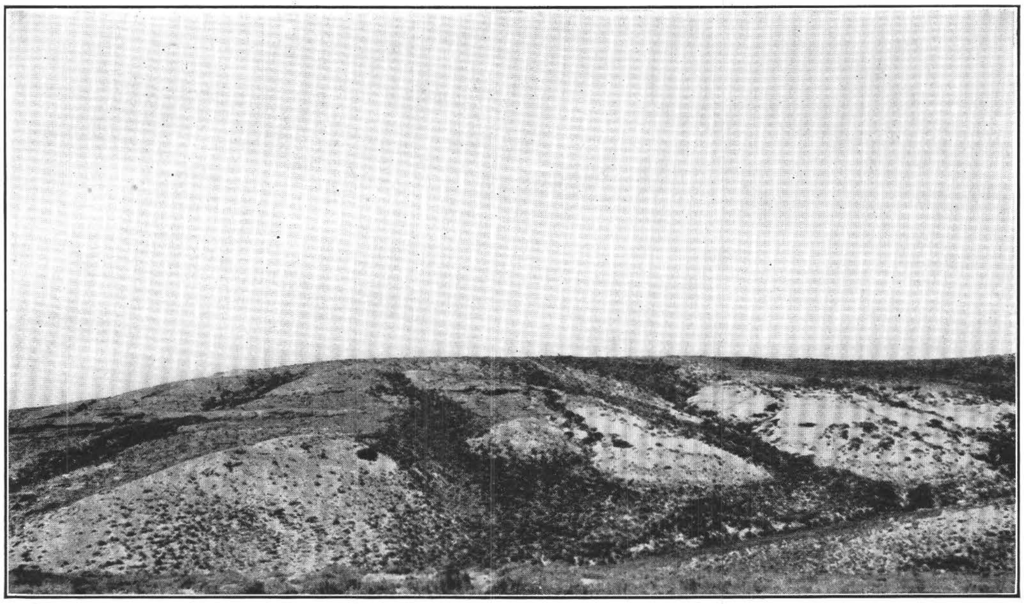


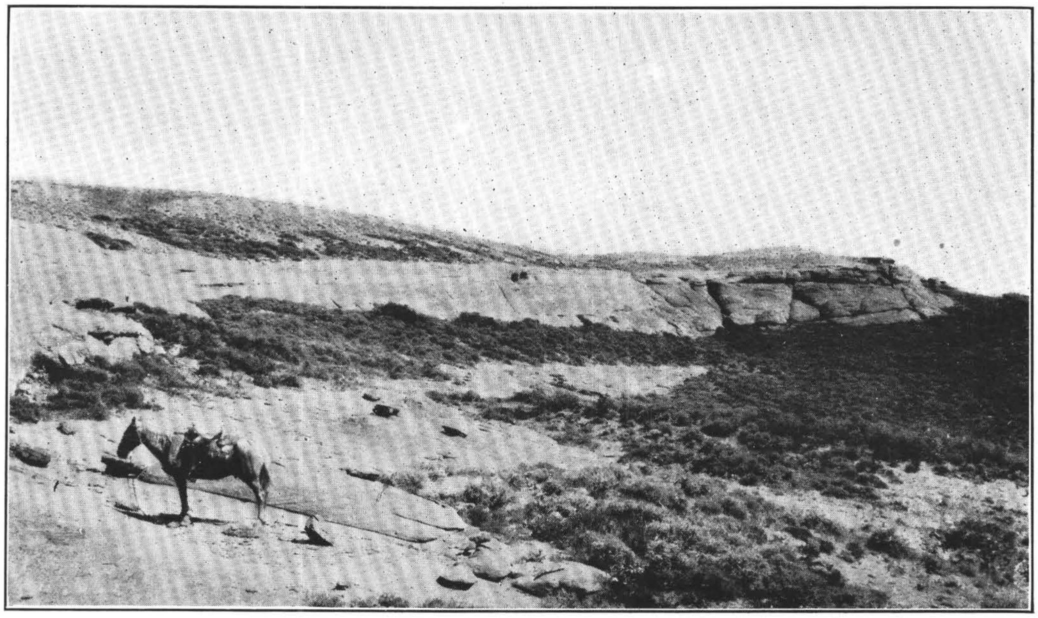
FIGURE 8.—Geologic map showing the southern extension of the Green River and Wasatch formations in White Mountain, Wyo., and the type locality of the Tower sandstone lentil. (From U. S. Geol. Survey Bull. 702, pl. 1)



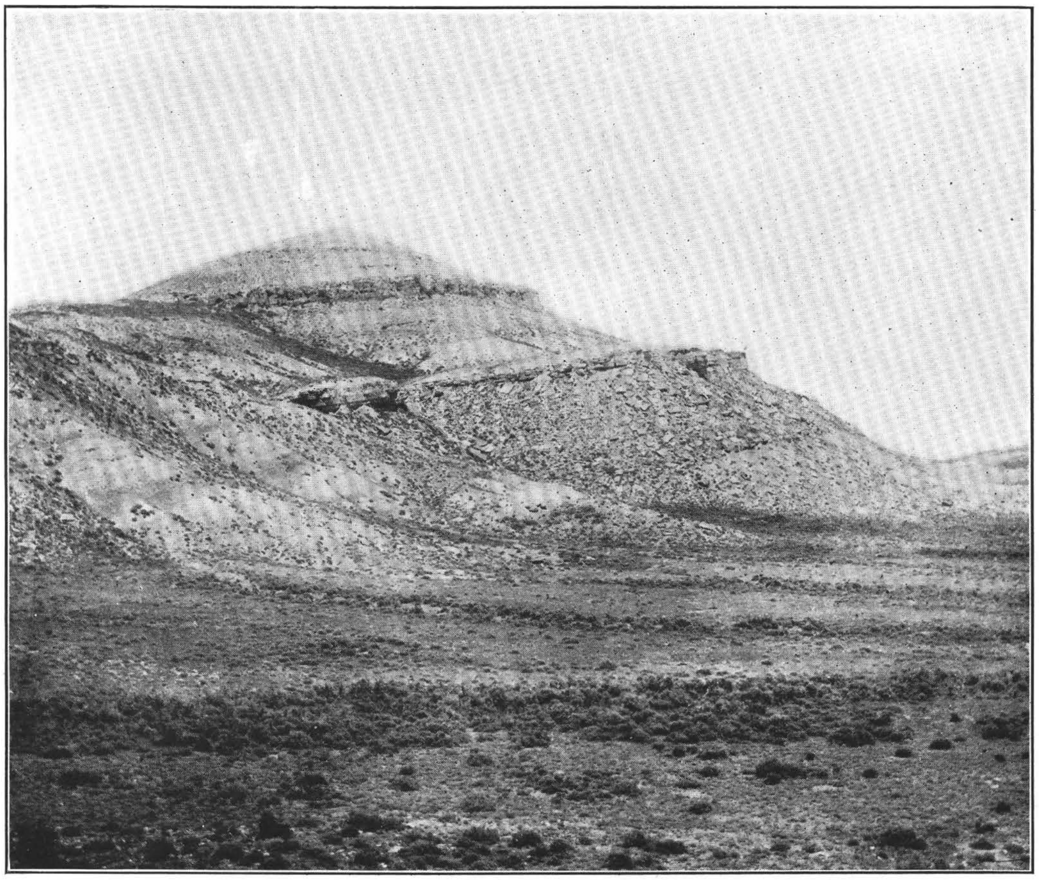
A. WHITE LANEY SHALE MEMBER OF GREEN RIVER FORMATION FAULTED DOWN AGAINST TIPTON TONGUE OF THE SAME FORMATION IN NORTHWEST CORNER OF SEC. 1, T. 24 N., R. 104 W., WYO.

B. REMNANTS OF TOWER SANDSTONE LENTIL OF GREEN RIVER FORMATION CAPPING "THE TOWERS" ABOUT A MILE NORTHWEST OF GREEN RIVER, WYO.

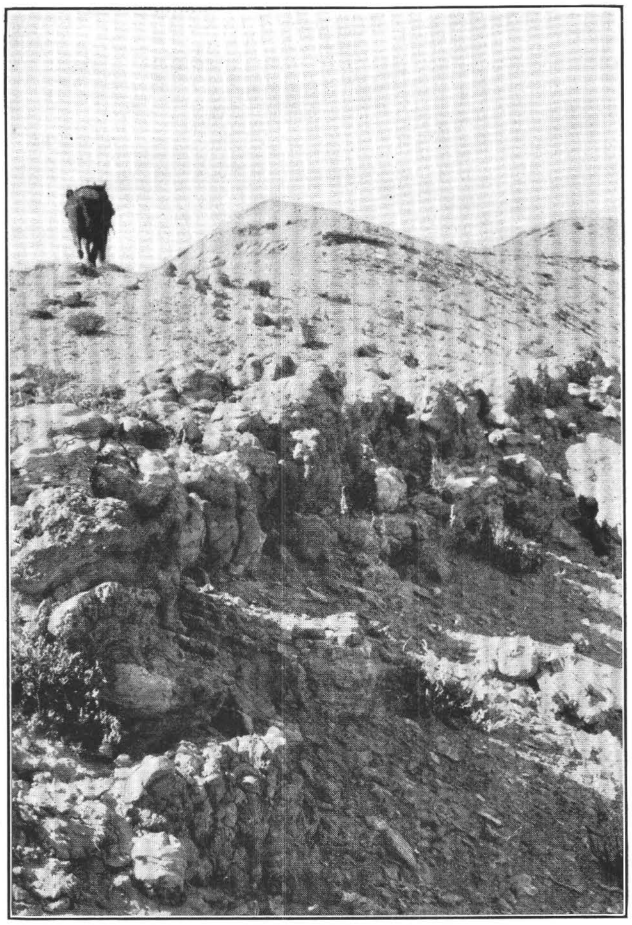
Photograph by W. T. Lee



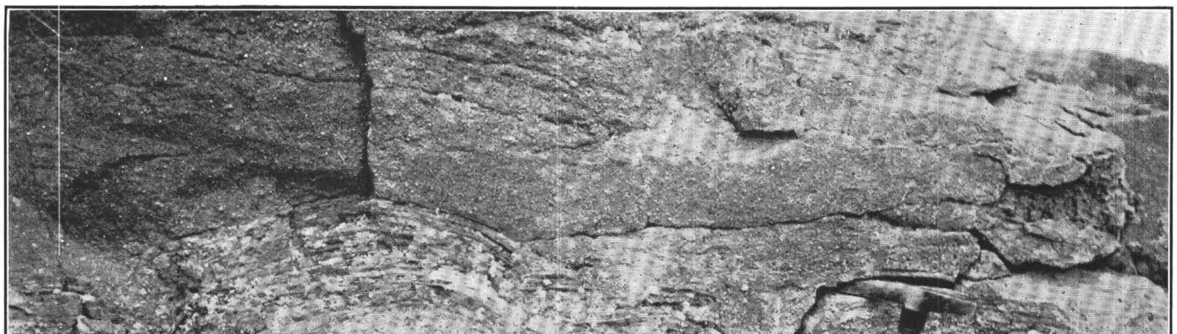
A. LARGE SANDSTONE LENS IN TIPTON TONGUE OF GREEN RIVER FORMATION IN SEC. 1, T. 24 N., R. 104 W., WYO.



B. LARGE BASAL OOLITIC LIMESTONE AND HIGHER SANDSTONE LENSES OF TIPTON TONGUE OF GREEN RIVER FORMATION FAULTED DOWN AGAINST VARIEGATED CLAY OF WASATCH FORMATION IN E. ½ SEC. 22, T. 25 N., R. 103 W., WYO.



A. LARGE CALCAREOUS ALGA REEF NEAR TOP OF GREEN RIVER FORMATION IN N. ½ SEC. 12, T. 23 N., R. 102 W., WYO.



B. CALCAREOUS ALGA REEF INTIMATELY ASSOCIATED WITH OOLITIC AND PISOLITIC LIMESTONE AT BASE OF TIPTON TONGUE OF GREEN RIVER FORMATION IN SEC. 22, T. 25 N., R. 103 W., WYO.

The lower part of the reef is broken and recemented by oolitic limestone

sists of finely laminated shale, ostracode-bearing limestone, limestone, oolite, and alga reefs but no sandstone. Northwestward from that line sandstone becomes more and more abundant. Near the line the sandstone is usually limy, micaceous, very fine grained, and in thin, relatively persistent beds. Rarely this fine limy sandstone shows cross-bedding on a minute scale.

Toward the northwest the sandstone becomes more massive or more cross-bedded and the sand grains become larger until in local lenses the pebbles are as much as half an inch in diameter. These pebbles and coarser sand grains, largely of quartz and feldspar, are either sharply angular or only slightly rounded. The feldspar grains are commonly glassy and have bright cleavage surfaces. In this direction also the sandstone becomes more and more lenticular until in the western part of the area the lenses have all the features characteristic of stream-channel deposits (Pl. LXI, *A*).

In White Mountain, southwest of this area, there is a similar lithologic change in the Tipton northward from Fourteenmile Spring. (See fig. 8.)

The numerous stream-channel deposits become evenly bedded, finer grained, and thinner to the south and southeast and eventually grade into finely laminated shale. These facts clearly indicate that the source of the sediments was to the north, and as they pass from fluviatile to lacustrine sediments in a general southeasterly direction it seems probable that the trend of the shore line was northeastward in this locality. The shore line could not be located accurately, because of insufficient exposures and because it evidently migrated with changes in water level, but it probably should be placed where cross-bedding in the sandstone lenses becomes reduced greatly in scale and the greater portion of the sand assumes a distinct and fairly regular bedding. It was found in the field that where the sandstone assumes a lacustrine aspect the lime content increases materially.

It is probable that the Wind River Mountains, about 20 miles north of this area, constituted the land mass from which streams carried these sediments. The arkosic nature of the stream-channel deposits as well as the sharp angularity and freshness of the individual grains is in harmony with this suggestion, for the deeply dissected core of the Wind River Range consists of coarsely crystalline granite.

That the Wind River Mountains were sufficiently high above the basin of deposition to furnish abundant rock waste in Eocene time seems amply proved by the studies of Blackwelder,[7] and it does not appear necessary to restate the evidence in this paper.

[7] Blackwelder, Eliot, Post-Cretaceous history of the mountains of central-western Wyoming: Jour. Geology, vol. 23, pp. 97-117, 193-217, 307-340, 1915.

Additional evidence that the source of the sediments was to the north is obtained from an examination of the relations between the Wasatch and Green River formations in this area. These formations interfinger in such a way that the lacustrine sediments of the Green River formation either thin or disappear entirely toward the north, whereas on the other hand the fluviatile sediments of the Cathedral Bluffs tongue of the Wasatch formation thin or even disappear to the south.

The Laney shale member of the Green River formation thins northward from about 200 feet in sec. 31, T. 24 N., R. 104 W., to less than 50 feet, and finally by the introduction of more and more thin fingers of green clay it loses its lithologic identity and passes over in sec. 3, T. 25 N., R. 102 W., into the typical fluviatile deposits of the Cathedral Bluffs tongue of the Wasatch formation. Throughout the remainder of the area the Morrow Creek member of the Green River formation, which itself becomes sandy and thins northward from more than 300 feet to about 100 feet in Oregon Buttes, in sec. 12, T. 26 N., R. 101 W., rests directly upon the Cathedral Bluffs tongue.

Near the head of Alkali Brook the Cathedral Bluffs tongue is about 200 feet thick, but at Steamboat Mountain it is only a little more than 100 feet thick. A more striking example, however, is to be seen in the western part of the area, where the same tongue of fluviatile clay thins from 200 feet in the north until it pinches out completely between the Laney shale member and Tipton tongue of the Green River formation about 16 miles to the southwest. (See Pl. LIX.)

BIOLOGIC EVIDENCE OF SHORE PHASES

From the preceding discussion of the larger relations of the several formations and their lithologic character it is clear that these rocks represent the marginal phases of lacustrine deposits and the closely related shore and fluviatile deposits. Many of the life forms associated with these phases of deposition are preserved in the deposits and furnish considerable information concerning the physical and biologic conditions under which the sediments were laid down. In addition they may serve as criteria for the recognition of lake-margin deposits in other areas where the lithology alone is not distinctive.

Calcareous alga reefs, oolites, pisolites, and ostracode-bearing limestones are present in abundance in the Tipton tongue and Morrow Creek member of the Green River formation in this area and deserve consideration in such a study of lacustrine sediments because of their value as indicators of the physical conditions that attended sedimentation. (See Pl. LXII, *A*.)

Calcareous alga deposits of recent origin variously described as water biscuit, nodular marl, algoid lake balls, or marlyte are evidently the modern representatives of the fossil alga reefs. An examination of the mode of occurrence of some of these recent forms is instructive. Pollock [8] describes algal pebbles in a Michigan lake as being abundant and more or less grown together in the shallow water near shore and becoming smaller and less numerous as the water deepens away from shore. Blatchley and Ashley,[9] in discussing the deposition of marl in James Lake, say: "Along much of the shore of the lake, particularly in the shallower water, the marl is markedly concretionary on top and often for 3 or 4 feet down." Clarke,[10] Powell,[11] and others have emphasized the rapidity of growth of such deposits in very shallow lake margins. Calcareous reefs, very probably of the same origin as the fossil alga reefs in the Green River formation, were formed on the wave-cut terraces in Lake Lahontan [12] when the lake was deep and of broad extent.

It is perhaps germane to note here that at several localities the alga reefs of the Green River formation are broken as if by wave action and that the broken fragments are at some places associated with rather coarse sand and at others with fine limy sand that shows abundant mud curls. Many of the fossil alga reefs in this area are immediately overlain by clean, well-sorted medium-grained sand, which is locally unconsolidated. Such a deposit of sand at least suggests the effects of the currents or waves common in shallow water. Again, some of the algal deposit was formed around logs, and in sec. 23, T. 25 N., R. 103 W., near the top of the Tipton tongue of the Green River formation, there are a large number of hollow cylinders of algal limestone 1 to 2 feet in outside diameter, 8 to 10 inches in inside diameter, and 6 to 8 feet in length. The inner surface of these log cases exhibits undoubted woody structure. Branching is also common in them.

The writer believes that the oolites and pisolites of the Green River formation in this area were deposited through the agency of microscopic plants, either algae or bacteria, and therefore that they were formed under physical conditions at least not widely divergent from those which produced the alga reefs. (See Pl. LXII, *B*.) In Ore Lake, Mich., Pollock [13] observed vast numbers of minute spherical or subspherical grains, virtually a mixed oolite and pisolite, forming in the shallow lake margins. Pisolite is now forming at the shores of Pyramid Lake, Nev.,[14] a lake which has less than 0.5 per cent of solids in solution. The formation of oolite on the shores of salt lakes and on marine beaches is well known. Nearly all of the recent oolite that is similar to the fossil oolite of the Green River formation in both microscopic and megascopic features is being formed either at or very close to the strand line.

In addition to the calcareous alga reefs and relatively abundant oolite and pisolite in the lacustrine deposits of this area there are numerous beds composed almost entirely of ostracode shells. Only two of the several genera of ostracodes have been identified, and they both have a rather general distribution in depth and salinity of water, so that in themselves they are of little value as indicators of the physical conditions of the lake. So abundant are these shells, however, that in many places they form loosely consolidated beds from 1 to 3 feet thick. Interbedded with such pure shell limestones are large quantities of soft, finely laminated limy shale in which ostracode valves are conspicuous constituents. Such vast numbers of these organisms must have lived in the shallow, well-lighted, well-aerated, algae-rich margins of the water body in which these sediments were deposited.

In association with the ostracode-bearing limestone and oolite, other evidence of the same marginal conditions is found in the larval cases of trichopterous insects. These insects require considerable oxygen in the larval stage as well as such microscopic food plants as abound in shallow, well-lighted waters. The cases of these insect larvae were constructed of ostracode valves. Two new species of these fossil insects have been described by the writer.[15]

Plant remains, such as the impressions of *Equisetum* stems and the leaves of higher plants, are very common in the Morrow Creek member of the Green River formation and are of sporadic occurrence in the Tipton tongue. A few thin beds of carbonaceous shale composed largely of carbonized plant remains also occur in the Green River formation of this area. The floral evidence from these rocks thus appears to be in accordance with the hypothesis that they were deposited near the margins of the ancient lake.

In addition to the evidence already stated, there exists some more or less fragmentary evidence—for example, in sec. 30, T. 25 N., R. 101 W., the mingling of the bones of aquatic and terrestrial vertebrates in a thin but persistent grit which the writer believes is a beach deposit in the Tipton tongue of the Green River formation. The bones associated there are the teeth and vertebrae of fish and fragments identified by J. W. Gidley as belonging to *Parameryx*, a small camel. Near the top of both the Tipton tongue and the Morrow Creek member of the Green River formation petrified wood is rather abundant. The value of petrified wood as an indicator of lake-margin conditions, however, is rather doubtful.

[8] Pollock, J. B., Michigan Acad. Sci. Twentieth Ann. Rept., p. 249, 1918.

[9] Blatchley, W. S., and Ashley, G. H., The lakes of northern Indiana and their associated marl deposits: Indiana Dept. Geology and Nat. Resources Twenty-fifth Ann. Rept., p. 81, 1900.

[10] Clarke, J. M., The water biscuit of Squaw Island, Canandaigua Lake, N. Y.: New York State Mus. Bull. 39, vol. 8, pp. 195–198, 1900.

[11] Powell, C., Observations on some calcareous pebbles: Minnesota Bot. Studies, vol. 3, pp. 75–76, 1903.

[12] Russell, I. C., Geological history of Lake Lahontan: U. S. Geol. Survey Mon. 11, p. 191, 1885.

[13] Op. cit., p. 249.

[14] Russell, I. C., op. cit., p. 168.

[15] Bradley, W. H., Fossil caddice-fly cases from the Green River formation of Wyoming: Am. Jour. Sci., 5th ser., vol. 7, pp. 310–312, 1924.

ORIGIN OF THE GREEN RIVER OIL SHALE

OIL SHALE OF THE LANEY SHALE MEMBER

Description of the Laney shale member of the Green River formation has purposely been deferred up to this point, because its deposition was evidently attended by physical conditions that differed from those which produced the underlying and overlying sediments. This member consists entirely of exceedingly fine-grained sediments which contain in addition to the clastic mineral matter varying proportions of organic matter. The organic content ranges from almost none in the barren limy shale to as much as 36 per cent in the richest oil shale found in this area. On distillation this rich shale yielded oil at the rate of 35.5 gallons to the short ton. All gradations between these two extremes in organic content exist, but the greater part of the shale in the Laney shale member in this area is relatively poor in organic matter. The sample that yielded 35.5 gallons of oil to the ton came from a thin bed of oil shale in sec. 2, T. 24 N., R. 104 W. North and east of this place the organic content decreases rapidly, and for the last several miles of the Laney shale member all the shale and limestone is quite barren of organic matter. The physical conditions that attended the deposition of the barren part of the Laney shale member of the Green River formation were probably similar to those that attended the deposition of the Tipton tongue of the Green River formation already described. The mode of origin of that part of the Laney shale member which contains an appreciable content of organic matter involves the more specific question of the origin of the oil shale.

PRELIMINARY CONCLUSIONS

Regarding the conditions of deposition of the Green River oil shale, the preliminary conclusions from the field and microscopic study of the last two years on the oil shale and microscopic flora of the Green River formation may be stated briefly at this time. The detailed evidence upon which these conclusions are based will be presented in another paper, the completion of which awaits more extended field observation and microscopic study.

ORGANIC CONSTITUENTS

Evidence of several kinds leads the writer to believe that the dominant part of the organic matter in the oil shale of the Green River formation consists of the remains of planktonic organisms that lived in the surface waters of the ancient lake. Probably most of these organisms, which after death accumulated on the lake bottom as a putrescent ooze, were microscopic plants. Many of the living planktonic algae are rich in a fatty or oily substance which is the product of their metabolism and may also serve in part for buoyancy. There is considerable evidence to indicate that the Eocene representatives of the plankton flora were similar in this respect. As the zooplankton depends largely upon the phytoplankton for food, there was very probably an abundant microscopic fauna, but it remains to be demonstrated to what extent it contributed to the organic ooze that became oil shale when it was subsequently lithified. The only microscopic animal remains so far known in the Green River oil shale are very rare fragments of insects. In the associated beds, however, a large invertebrate and vertebrate fauna has been found.

Pollen and spores constitute a much smaller part of the organic matter than the remains of plankton, and as they were transported by the wind they are irregularly disseminated through the deposit. Nevertheless they produce oil upon distillation, and consequently where they occur in abundance the shale is enriched.

The more highly organized plants that grew on the land adjacent to the shores and the larger aquatic plants that inhabited the shallow lake margins contributed very little to the organic shale. Aside from the pollen and spores which these plants produced they are represented in the oil shale by only scattered fragments of a lignified or suberized cell, or group of cells. Such fragments of higher plants are usually somewhat strongly humified or even carbonized and yield little if any oily distillate. Precipitated humin acid, also poor in oily distillates, is apparently inconspicuous in the Green River oil shale. Under certain conditions in small ponds and in the shallow margins of large lakes a type of oil shale has formed which contains in addition to the plankton material considerable humified débris and probably also precipitated humin acid, both of which were derived from the more highly organized land and aquatic plants. Such an oil shale is likely to be of only local occurrence and therefore of only small commercial importance. An oil shale of this kind occurs in the Fuson formation near Cambria, Wyo.

The evidence thus far accumulated by the writer suggests that there are two entirely distinct types of oil shale, the characteristics of which are determined largely by the depth of water in which the original deposit formed.

That type of oil shale which in the Green River formation of both the Green River and Uinta basins yields the most oil upon distillation appears to have resulted from a periodic concentration of organic matter due to a very pronounced reduction in volume of the water body. This shale is characteristically black on the fresh surface and weathers bluish white. The lake or lakes, as the case may be, in which this oil shale formed were probably less than 100 feet in depth at the initiation of any given cycle and supported a luxuriant plankton flora and fauna. It seems probable that the reduction in depth and volume of the lakes was accompanied by stagnation and an increase in temperature of the water, factors both of which would stimulate a vastly greater production of the plankton and hence increase the volume of the organic ooze. The facts indicate that such periodic reductions of volume accompanied by the augmented production of plankton proceeded in most places until there remained only a sirupy or gelatinous mass of putrescent organic matter on the bottoms of the lake basins.

Desiccation appears to have been the final phase of some of these periodic reductions in volume, for some of the oil shale is mud cracked and brecciated, and in places the bedding planes are studded with molds of salt crystals. In the samples of this brecciated oil shale so far examined no pyrite has been found, but many of the other rich oil shales of otherwise similar character contain pyrite in varying amounts disseminated in minute grains and blebs. When these shales were formed reducing conditions evidently persisted until lithification occurred, whereas the brecciated shale was probably exposed for a short time at least to oxidizing conditions. The absence of pyrite in the brecciated shale, although not conclusive, is suggestive of exposure to air.

Bacterial decomposition of the organic matter must have been effectively checked prior to lithification. It is not yet known whether this putrefactive decomposition was inhibited by the concentration of inorganic salts in solution or the concentration of toxins in the form of organic acids (the products of bacterial activity) or by the paucity of available water necessary to continued bacterial life. It seems probable that more than one of these factors or perhaps all acted simultaneously to produce the aseptic state necessary to the preservation of the organic matter.

The other type of oil shale—the ordinary lean and commonly limy shale of the Green River formation—as a rule yields an appreciably smaller quantity of oil to the ton on distillation. It is usually light brown or even dark chocolate-brown but rarely if ever black, and it weathers buff rather than bluish white. The intimate and consistent association of remains of fresh-water aquatic plants, insect larvae, crustaceans, and fish with this lean oil shale suggests that it accumulated in water bodies of a more permanent nature but at the same time of moderate depth, perhaps not exceeding 60 feet. This shale, then, probably derived its organic content from the accumulation on the bottom of planktonic organisms similar to those which constitute the water bloom of existing fresh-water lakes.

The cessation of bacterial activity in such an organic ooze would be dependent only upon the exclusion of sufficient water and oxygen for putrefaction, which would result from the compression due to the weight of later deposits. It is significant that the organic matter in this generally lean oil shale has been completely disorganized, presumably through the activity of bottom-dwelling organisms, such as certain fish, crustaceans, and nematodes, and of bacteria and fungi, whereas in the richer type of oil shale many of the microorganisms, spores, and pollen grains that go to make up the organic part of the shale have retained their original form and a few of them even their internal structure.

Conditions approaching those outlined above accompanied the deposition of part of the Tipton tongue of the Green River formation in this area and resulted in several beds of very low grade papery oil shale. These shales will yield less than 10 gallons of oil to the short ton on distillation. In other parts of the Green River Basin the Tipton tongue of the Green River formation contains oil shale of a higher grade.

Whatever kind of organic matter accumulated on the substratum, it was subjected to a more or less thorough but slow putrefaction, in which bacteria, saprophytic fungi, and similar microorganisms effected a selective decomposition, the more cellulosic parts of the organisms and plant parts being removed and the fatty, waxy, and resinous parts remaining as resistant matter, to be later lithified and thus preserved as oil shale.

CHEMICAL CHANGES

The original organic ooze has undergone complex and probably numerous chemical changes since its accumulation on the lake bottoms. Very little is known regarding these changes except that the trend was evidently toward the elimination of oxygen with a corresponding relative increase in hydrogen and carbon. Part of this change may have occurred during the accumulation of the dead organisms on the substratum, through the agency of bacteria. The remainder of the series of changes may have occurred very gradually subsequent to lithification as purely chemical reactions, perhaps assisted or even entirely controlled by the presence of inorganic matter in a colloidal state.

E. T. Erickson, of the United States Geological Survey, is at present engaged in a protracted study of the chemistry of these complex changes. Lacustrine organic oozes form the starting point of some of these investigations.

MINERAL CONSTITUENTS

Concomitantly with the accumulation of the organic constituents occurred the deposition of varying amounts of finely divided aluminous material, calcium carbonate, and minute particles of quartz. In the Laney shale member of the Green River formation the quantity of calcite far exceeds that of the other mineral constituents. The calcite is distributed pretty uniformly through the shale in very fine particles and may have been deposited indirectly through the agency of bacteria. According to Kellerman [16] the precipitation of calcium carbonate may take place "by the combined action of ammonia, produced by bacteria either by the denitrification of nitrates or by the fermentation of protein, together with carbon dioxide, produced either through the respiration of large organisms or the fermentation of carbohydrates by bacteria." There was certainly sufficient ammonia and carbon dioxide in association with the putrefying plant and animal matter at the bottom of the Green River lake to effect such a precipitation, if there was an adequate supply of lime salts. Kellerman's experiments [17] showed that ordinary crystals of calcite could be produced by a growth of mixed cultures of bacteria in either salt or fresh water.

CLIMATE

The climate that attended the deposition of the Green River formation must have been warm and moist enough to support a luxuriant vegetation and yet of such a seasonal nature that it alternately favored and inhibited the growth of woody plants. It appears also that the area was subject to periodic droughts of sufficient length to produce very decided changes in the volume of large inland water bodies.

MEASURED SECTIONS

The following sections, measured by the writer and C. H. Dane, set forth in greater detail the lithologic character of the several parts of the Green River and Wasatch formations and their lateral variations. Beds described as low-grade oil shale yield less than 10 gallons of oil to the ton.

Sections of Tipton tongue of Green River formation in northern part of Sweetwater County, Wyo.

Locality 1, sec. 1, T. 24 N., R. 100 W.

	Ft.	in.
Shale, flaky, greenish gray; contains thin beds of ostracode limestone and abundant fish-bone fragments	4	9
Ostracode limestone; contains fish-bone fragments		6
Shale, flaky to lumpy, brown to chrome-yellow	3	
Interval concealed	5	2
Calcite parting, cone-in-cone structure		1
Shale, laminated, brown to greenish gray; contains a few thin beds of impure limestone	28	
Clay, olive-brown	1	
Clay, greenish gray	4	
Shale, flaky, greenish gray; alternates with brown laminated shale and thin beds of impure limestone	4	6
Limestone, buff; contains abundant ostracodes, fish-bone fragments, and clay balls	3	
Shale, flaky, greenish; alternates with brown paper shale and thin beds of sandy limestone; ostracodes numerous	4	6
Limestone, sandy		2
Shale, flaky to laminated, greenish gray and brown	5	
Limestone, finely crystalline, yellowish gray; contains many mud balls and mud curls	1	
Interval concealed	3	
Limestone, banded, hard		6
Limestone, oolitic	1	6
Shale, flaky, greenish gray	5	
Alga reef, mixed with sandy limestone		8
Shale and shaly limestone, laminated, gray	5	
Alga reef		8
Shale, flaky, greenish gray	3	
Limestone, oolitic; contains mud curls		8
Shale, flaky to lumpy, gray green	8	
Shale, papery	15	
Limestone, dense, sandy; concretionary	1	6
Shale, laminated, soft, limy, brown; ostracodes numerous; contains few beds of low-grade oil shale	12	
Limestone, sandy and oolitic	1	
Shale, alternately flaky and laminated, brown to gray; contains ostracodes	18	
Interval concealed, probably soft limy shale	25	
Alga reef; ostracodes between the nodes	1	
Shale, papery, bluish white	13	
Limestone, platy; contains many large gastropods, Unios, and ostracodes	3	
	179	5

Locality 2, sec. 1, T. 23 N., R. 102 W.

	Ft.	in.
Limestone, oolitic, thin bedded, buff; contains a few thin beds of sandy and limy shale	6	
Shale, platy, sandy, and limy	5	
Shale, thin, uniform bedding, soft, grayish green	3	
Alga reef, calcareous	1	6
Sandstone, very fine grained, soft; contains thin beds of buff paper shale	4	
Alga reef, concentric shells of large stools and pillars 10 inches high and 2 to 5 inches in diameter; reef is slightly silicified	5	
Shale, papery, soft, light brown; contains small amount of low-grade oil shale	8	
Limestone, oolitic, in part almost unconsolidated; ostracodes abundant in lower few inches	3	
Shale, laminated and papery; contains some beds of carbonaceous shale and small amount of low-grade oil shale	11	
Ostracode-bearing limestone, thick beds, gray to buff	2	
Shale, papery, brown; replete with ostracodes	8	
Clay, soft, greenish gray	3	
Sandstone, clayey and limy, dark gray; bedding is very irregular and evidently indicates current or wave agitation at time of deposition	11	
Clay, light gray	5	
Shale, flaky, soft, brown	15	
Shale, laminated, hard, bluish gray; low-grade oil shale	5	
Oolite; contains half-inch layer of alga deposit		8
Shale, laminated, blue-gray to buff; contains ostracodes		6
Alga reef		3
Shale, papery, blue-gray; low-grade oil shale	1	4
Shale, papery; low-grade oil shale; contains numerous thin beds of ostracodes		10
Ostracode-bearing limestone, buff	1	
Shale, papery, blue-gray; low-grade oil shale	1	
Shale and ostracode-bearing limestone; consists of alternating thin beds of laminated shale and ostracodes	2	6

[16] Kellerman, K. F., Relation of bacteria to deposition of calcium carbonate: Science, new ser., vol. 41, pp. 507-508, 1915.

[17] Idem, p. 508.

	Ft.	in.
Ostracode-bearing limestone, stained with limonite; contains many fish-bone fragments and edgewise conglomerate of shale pieces		8
Shale, soft, gray; contains many ostracodes		6
Limestone, sandy, gray to faint buff; contains gastropods, ostracodes, and Unios	1	
	115	9

Locality 3, sec. 25, T. 25 N., R. 102 W.

	Ft.	in.
Shale, limy, white	1	
Limestone, white		1
Shale, papery	3	
Limestone, banded, mud cracked		2
Shale, papery	4	
Alga reef, marbleized		5
Shale, papery	1	
Sandstone, cross-bedded on a small scale; contains beds of coarse angular quartz, grit, and stringers of small pebbles; bones of *Parameryx* and fish associated in the grits; beach deposit	13	2
Interval concealed	4	
Clay, gray	5	6
Shale, limy, brown	4	6
Limestone, thin bedded, sandy, white	6	6
Interval concealed	21	
Limestone, thin bedded, sandy, white	5	
Interval concealed	22	
Shale, papery; contains thin beds of ostracode-bearing limestone	5	
Limestone, massive; contains gastropods and ostracodes	2	6
	98	5

Locality 4, sec. 18, T. 24 N., R. 102 W.

	Ft.	in.
Top of bluff, approximately top of Tipton tongue.		
Limestone, hard, yellow-brown to gray; in part ostracode-bearing limestone	1	
Shale, sandy	8	
Sandstone, crudely bedded, limy, fine grained, yellow-brown	4	6
Sandstone, thin bedded, shaly, fine grained, gray		4
Sandstone, crudely bedded, hard, micaceous; contains large fragments of alga reef		5
Sandstone, platy, micaceous, very fine grained, greenish gray	1	6
Alga reef; breaks into fragments resembling goose-egg shell		6
Shale, fissile, sandy and limy, micaceous, greenish gray	2	
Limestone, porous, sandy; contains some ostracodes	2	
Shale, papery, soft, yellowish brown	1	6
Shale, papery, slate-gray	2	6
Ostracode-bearing limestone, sandy, buff		6
Limestone, dense, white		1
Sandstone, massive, fine grained, micaceous; contains round brown concretions and lenses of dark-brown grits which consist of angular grains of quartz and fresh feldspar	4	
Shale, very sandy, platy, hard, gray	4	
Sandstone, crudely bedded and cross-bedded, fine grained, micaceous, light gray to buff	14	
Limestone, shaly, poorly bedded, hard, light gray to white. This zone persists through several townships surrounding this place	37	
Shale, thin regular bedding, somewhat clayey, soft, brown to greenish gray	7	6
Shale, papery, limy, soft, brown to buff	3	6
Alga reef; large well-rounded stools	2	
Shale, papery, soft, brown		10
Alga reef		1
Shale, flaky, very soft, brown to light gray	1	4
Ostracode-bearing limestone, buff		8
Shale, bedding obscure, sandy, light gray	2	
Ostracode-bearing limestone	2	
Limestone, massive or platy, hard, rather coarsely crystalline, buff; contains abundant ostracodes	5	
Sandstone, limy, fine grained, hard	1	
	109	6

Locality 5, sec. 18, T. 24 N., R. 103 W.

	Ft.	in.
Sandstone, limy, thin bedded and cross-bedded, micaceous, white to yellowish gray	1	6
Sandstone, limy, soft; contains some oolite	2	
Limestone, thin but very irregular bedding	8	
Sandstone, limy, pale green; has a spherulitic texture due to grouping of sand grains	2	
Sandstone, massive and cross-bedded, limy	9	
Limestone, poorly bedded, white	2	
Limestone and limy shale, white to yellowish gray	21	
Interval concealed	22	
Oolite, bedded; contains the fossil larval cases of trichopterous insects	1	
Pisolite	1	
Oolite; contains layers of ostracodes and a few gastropods	14	
Alga deposit; consists of an aggregate of small spheroidal lumps as much as 1 inch in diameter, which strongly resemble the so-called algoid lake balls of modern lakes	1	
Limestone, clayey, light gray; contains abundant ostracodes	1	
Limestone, massive, hard, light gray; contains large quantities of ostracodes and near the top many gastropods	2	
	87	6

Locality 6, sec. 25, T. 25 N., R. 103 W.

	Feet.
Sandstone, medium grained, thin regular bedding, limy, hard, light yellow-gray. Some of the thin beds are cross-bedded on a minute scale. Toward the top the sandstone becomes more massive and cross-bedding is more conspicuous	51
Interval concealed	12
Shale, very sandy, thin bedded, gray	11
Clay, soft, gray; alternates with thin beds of unconsolidated sand	6
Clay, soft, limy, gray and brown	15
Shale, very limy, thin bedded to papery, gray to brown	16
Clay, laminated, light greenish gray	11
Alga reef; in part broken and recemented	2
Clay, soft, green	2
Limestone, oolitic, white to buff; contains great numbers of ostracodes and a few gastropods	7
Ostracode-bearing limestone, hard, buff; contains some oolites and many gastropods	7
	140

Sections of Cathedral Bluffs tongue of Wasatch formation in northern part of Sweetwater County, Wyo.

Locality 7, sec. 21, T. 24 N., R. 101 W.

	Ft.	in.
Top of ridge; approximate base of Morrow Creek member of Green River formation.		
Clay, hard, gray	2	5
Clay, mauve	3	
Clay, hard, gray	7	6
Limestone; caliche (?)		6
Clay, hard, yellow	4	6
Limestone, caliche (?)	1	
Clay, hard, yellowish gray	37	
Clay, platy, hard, limy, gray	1	
Clay, soft, gray to yellowish gray	11	
Clay, hard, very limy; breaks into chips	5	7
Sand, unconsolidated, yellowish gray	6	
Clay, greenish gray; contains turtle-bone fragments	8	
Clay, greenish gray; contains beds of reddish sandstone	27	6
	115	

Locality 8, sec. 14, T. 25 N., R. 102 W.

	Ft.	in.
Clay, carbonaceous, nearly black	1	
Clay, gray-green	5	
Clay, irregularly platy, white	2	
Clay, massive, hard, white		5
Clay, soft greenish gray, alternating with hard white clay	14	6
Clay, dense; has conchoidal fracture	1	
Clay, limy, white; breaks into flat chips	10	6
Clay, light greenish gray	5	6
Clay, banded, dark and light greenish gray	16	6
Clay, hard, white, blocky fracture	2	6
Clay, dark greenish gray	5	6
Interval concealed	5	6
Clay, soft, gray; contains many isolated stools of calcareous alga reef	6	
Clay, greenish gray	2	
Clay, sandy, greenish gray	8	6
Sandstone, very friable, distinct but irregular bedding, light yellowish gray	7	6
	93	11

Section of Morrow Creek member of Green River formation at locality 9, sec. 17, T. 23 N., R. 102 W., in northern part of Sweetwater County, Wyo.

	Ft.	in.
Wyomingite flow capping Steamboat Mountain.		
Shale, very limy, hard, platy	3	
Pisolite, completely silicified		6
Sandstone, very fine grained, limy, gray to buff, regularly bedded	70	
Limestone, hard, slightly sandy, thin bedded, gray to faint buff	5	
Shale, sandy, and fine-grained sandstone, brownish gray	12	
Alga reef, completely silicified	1	
Sandstone, almost unconsolidated, medium to fine grained, gray; contains conspicuous amount of biotite	10	
Limestone, shaly, hard, irregularly platy; carries plant impressions		6
Sandstone, limy, fine grained, soft, buff banded with limonitic stain	15	
Interval concealed, probably soft shaly sandstone	142	
Limestone, sandy at base, grading upward into shaly limestone, ash-gray; carries abundant plant remains	2	
Sandstone, almost unconsolidated, fine grained, buff	1	
Sandstone, very limy, fine grained, irregularly bedded.	5	3
Shale, flaky, crudely laminated, greenish gray	4	
Shale, very soft, paper-thin laminae, buff	1	
Shale, finely laminated, light brown	4	8
Limestone, shaly, hard, irregularly bedded, buff	3	6
Shale, rather thick laminae, pale greenish gray	5	10
Shale, limy, soft, laminated; bedding planes wavy	2	6
Clay, hard, blocky, greenish buff	1	6
Limestone, shaly, irregularly bedded		6
Shale, soft, limy, paper-thin laminae; contains a few thin beds of low-grade oil shale	25	
Shale, flaky, greenish gray	5	
Shale, papery, brown	3	
Limestone, sandy		½
Shale, carbonaceous, black; contains abundant plant fragments		6
	324	3½

CORRELATION OF THE EOCENE FORMATIONS IN MISSISSIPPI AND ALABAMA

By Wythe Cooke

INTRODUCTION

During Eocene time the site of the boundary between the States of Mississippi and Alabama fell within the transition zone between the Mississippi embayment and the open Gulf of Mexico. That different types of deposition proceeded simultaneously within these two regions may be inferred from the different facies which deposits of the same age exhibit on opposite sides of the State line. In general, much clay and carbonaceous material were laid down in Mississippi, while shell marl, laminated sand, and limestone were being formed in Alabama. The purpose of this paper is to point out the equivalences of formations of different facies in the two States. The correlation adopted is shown in the following table, all the formation names in which have been previously used, except Kosciusko sandstone, a new name proposed for a member of the Lisbon formation.

Correlation of Eocene formations in Mississippi and Alabama

	Mississippi			Alabama	
	Jackson formation	Yazoo clay member		Jackson formation	Ocala limestone east of Tombigbee River
	Jackson formation	Moodys marl member		Jackson formation	Ocala limestone east of Tombigbee River
Claiborne group	Yegua formation			Gosport sand	
Claiborne group	Lisbon formation	Kosciusko sandstone member		Lisbon formation	
Claiborne group	Lisbon formation	Winona sand member		Lisbon formation	
Claiborne group	Tallahatta formation			Tallahatta formation	
Wilcox group	Grenada formation		Overlapped area	Hatchetigbee formation	
Wilcox group	Absent		Overlapped area	Bashi formation	
Wilcox group	Holly Springs sand			Tuscahoma formation	
Wilcox group	Overlapped near Tennessee boundary	Ackerman formation	Overlapped area	Nanafalia formation	
Midway group	Porters Creek clay	Tippah sandstone member	Unexplored area	Naheola formation	
Midway group	Porters Creek clay			Sucarnochee clay	Overlapped area
Midway group	Clayton formation			Clayton formation	

The Eocene of the Gulf region is commonly divided into four parts—the Midway, Wilcox, and Claiborne groups and the Jackson formation. The types of the Midway, Wilcox, and Claiborne groups are based on the superb sections of Eocene strata exposed along Alabama and Tombigbee rivers. These sections, as interpreted by Prof. Eugene A. Smith and his associates, have long been the standard for comparison with sections in other parts of the Gulf Coastal Plain. The type of the youngest division of the Eocene, the Jackson formation, is in Mississippi.

MIDWAY GROUP

The Midway group is divisible into three formations—the Clayton formation (at the base), the Porters Creek or Sucarnochee clay, and the Naheola formation. These three seem to constitute a conformable series but at places may be separated from one another by local unconformities. The group is set off from the underlying Cretaceous rocks by a profound unconformity and from the overlying Wilcox group by a less conspicuous break.

The Clayton is thickest in the neighborhood of Chattahoochee River, the eastern boundary of Alabama, and thins toward the west. In western Alabama and in Mississippi it is reduced to a thin bed of limestone, and over a considerable area in both States it is completely overlapped by the Porters Creek or Sucarnochee clay. The Porters Creek, on the other hand, is thickest in Tennessee or Mississippi and pinches out entirely or is completely overlapped about midway across Alabama. It is probable that the two formations are partly contemporaneous, but the base of the Clayton is doubtless older than any part of the Porters Creek. The Naheola formation, consisting prevailingly of highly micaceous yellow to red sand, extends across Alabama into Mississippi at least as far north as De Kalb. The Tippah sandstone member, at the top of the Porters Creek clay in northern Mississippi, is probably of the same age as the Naheola formation, and it is not unlikely that the two could be united on the map by more detailed field work. It is perhaps significant that deposits of bauxite occur in clays tentatively correlated with the Naheola formation in Henry County, Ala., and also above the characteristic Porters Creek clay and beneath lignitiferous beds of the Ackerman formation (Wilcox group) at several places in Mississippi.

WILCOX GROUP

The formations of the Wilcox group in Mississippi differ much more markedly from those of the typical Wilcox of Alabama than the Midway formations in Mississippi differ from the Midway of Alabama. The State line lies not far from a natural boundary or transition zone which separates areas differing in type of deposists. It has been necessary to assign different names on opposite sides of the State line to several divisions of the Wilcox group.

The classic work of E. A. Smith and others, culminating in 1894 in their report on the geology of the Alabama Coastal Plain,[1] separated the Wilcox group of Alabama into four formations—the Nanafalia (lowest), Tuscahoma, Bashi, and Hatchetigbee. The first separation of the Wilcox group of Mississippi into formations was made in 1913, by E. N. Lowe,[2] who named the Ackerman (lowest), Holly Springs, and Grenada formations. Two years later [3] he added the "Woods Bluff formation," an alternate name for the Bashi formation, basing his recognition upon fossils identified by me. Berry [4] in 1917 pointed out the presence of the Hatchetigbee formation near Meridian.

The Nanafalia formation, which forms the base of the Wilcox group in Alabama, extends from Chattahoochee River at Fort Gaines, Ga., as far west as the junction of Yantley and Tickabum creeks in Choctaw County but has not been recognized in Mississippi. It contains a considerable proportion of hard rock resembling the buhrstone of the Tallahatta formation (of the Claiborne), which distinguishes it from the other parts of the Wilcox group, and it is further distinguished by carrying a great profusion of *Ostrea thirsae*.

In Mississippi the position at the base of the Wilcox group is occupied by the Ackerman formation, which is most extensively developed in the middle part of its belt of outcrop and pinches out near the Tennessee line on the north and near the Alabama line on the east. It consists of gray, rather massive clays, some of which are lignitic, and contains a peculiar flora. No marine fossils have been found in it. The Ackerman formation is tentatively correlated with the Nanafalia formation on the basis of its apparent stratigraphic position, but it may be equivalent to the lower part of the Tuscahoma formation of Alabama.

The Tuscahoma formation extends entirely across Alabama and abuts against the Holly Springs sand at the Mississippi line. Its most characteristic lithologic facies are very fine laminated gray sand and clay and yellow sand containing angular tilted blocks of laminated clay. Both of these facies are found also in the Holly Springs sand in eastern Mississippi. It is obvious that the Holly Springs is equivalent to at least part of the Tuscahoma, but whether or not both formations occupy the same stratigraphic interval would be difficult to prove. No marine fossils have been found in the Holly Springs to compare with a rather characteristic fauna in the type

[1] E. A. Smith, Johnson, L. C., and Langdon, D. W., jr., Report on the geology of the Coastal Plain of Alabama, Alabama Geol. Survey, 1894.

[2] Preliminary report on iron ores of Mississippi: Mississippi Geol. Survey Bull. 10, pp. 23-25, 1913.

[3] Mississippi Geol. Survey Bull. 12, p. 71, 1915.

[4] Berry, E. W., Geologic history indicated by the fossiliferous deposits of the Wilcox group (Eocene) at Meridian, Miss.: U. S. Geol. Survey Prof. Paper 108, p. 62, 1917.

area of the Tuscahoma, and too few plant remains are known from the Tuscahoma to furnish an adequate basis for comparison with the large flora of the Holly Springs.

The Bashi formation crops out along a narrow band extending nearly across Alabama but apparently is covered by an overlap of Hatchetigbee clays in western Choctaw County, near the Mississippi line. In Mississippi it has been recognized at only two localities near Meridian, but shells reported by Hilgard [5] from sec. 33, southwest of Marion and 2 or 3 miles north of Meridian, although referred by him to the Claiborne, probably came from the Bashi formation. The characteristic feature of the Bashi is a marl bed which has become locally indurated into gray pillow-like nodules of speckled marlstone or impure limestone. The marl at most places contains a large and varied fauna of mollusks.

Overlying the Bashi formation at Meridian and apparently overlapping for several miles beyond the Bashi is the Hatchetigbee formation, which is made up of brown or chocolate-colored, more or less carbonaceous clay and gray sand. In Mississippi the Hatchetigbee appears to be restricted to Lauderdale County, of which it covers somewhat more than 300 square miles, and the northeast corner of Clarke County. In Alabama its belt of outcrop extends across the State but is interrupted by overlaps of younger formations at the eastern extremity. Fossil leaves taken from Hatchetigbee clay at Meridian correlate the formation closely with the Grenada of northwestern Mississippi.[6] The Grenada formation, which is very similar in appearance to the Hatchetigbee, has been mapped from the vicinity of Duck Hill, Montgomery County, Miss., northward to the Tennessee line and is known to extend for a considerable distance into Tennessee.

CLAIBORNE GROUP

The Claiborne group is divided into three formations—the Tallahatta (lowest), Lisbon, and Yegua formations in Mississippi and the Tallahatta and Lisbon formations and Gosport sand in Alabama.

The Tallahatta formation extends from Grenada County, Miss., where it emerges from beneath the loess, eastward across Mississippi and Alabama and is still recognizable across Chattahoochee River at Fort Gaines, Ga. The formation nearly everywhere is easily identifiable by its characteristic lithology, consisting chiefly of brittle claystone or diatomaceous earth and hard sandstone with angular lumps of claystone, but in eastern Alabama these rocks are not conspicuous and most of the formation is composed of loose sand. Crider [7] and Lowe [8] included in the Tallahatta certain beds of quartzitic to granular sandstone which are most extensively developed in Attala and adjoining counties of Mississippi but are here regarded as a local facies of the Lisbon formation. Lowe divided the Tallahatta formation into two parts—a lower, called the Winona sand, and an upper, called the "Basic claystone." He regarded the sandstone of Attala County as equivalent to the "Basic claystone," which is typical Tallahatta formation, but the buhrstone of the Tallahatta can be traced beneath the typical Winona, which underlies the sandstone. The Winona is here treated as the basal member of the Lisbon formation.

In Alabama the Lisbon formation consists of two parts to which individual names have not been applied. The lower part consists chiefly of fine yellow or reddish sand and pale-green flaky clay. The upper part is made up of calcareous clay, impure limestone, or shell marl.

Lowe [9] has divided the Lisbon of Mississippi into four members— the "Enterprise green marl" (lowest), "Decatur sand," "Wautubbee marls," and "Cockfield beds." The last is usually regarded as synonymous with the Yegua formation of Texas and Louisiana and is treated as an independent formation overlying the Lisbon. The names "Enterprise" and "Decatur" have been dropped because they had already been used for a shale and a limestone in Kansas and Tennessee.

The "Enterprise marl," named from a village in Clarke County, contains a great deal of glauconite, which, on weathering, gives rise to highly ferruginous red beds. These red beds are perhaps the most conspicuous member of the Lisbon formation and can easily be traced northwestward along a belt adjacent to the outcrop of the Tallahatta formation. They appear to merge into the typical Winona sand. As the name "Enterprise" is preoccupied, the Winona sand is here redefined so as to include the typical Winona sand of Montgomery County and the typical "Enterprise marl" of Clarke County but to exclude the sands at the base of the Tallahatta formation in Lauderdale County which were erroneously correlated with the Winona by Lowe.

Above the Winona red beds lie sand beds called the "Decatur sand" by Lowe. The ledges of hard sandstone in Attala County referred to in the discussion of the Tallahatta formation appear to represent an indurated facies of these sands. The name Kosciusko sandstone member is here proposed as a designation for the ledges of saccharoidal to quartzitic

[5] Hilgard, E. W., Geology and agriculture of the State of Mississippi, p. 124, 1860.

[6] Berry, E. W., Geologic history indicated by the fossiliferous deposits of the Wilcox group (Eocene) at Meridian, Miss.: U. S. Geol. Survey Prof. Paper 108, pp. 61-72, 1917. This correlation was suggested by Lowe in Mississippi Geol. Survey Bull. 12, p. 72, 1915.

[7] Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. 283, pp. 29-32, 1906.

[8] Lowe, E. N., Mississippi, its geology, geography, soil, and mineral resources: Mississippi Geol. Survey Bull. 12, pp. 72-76, 1915; Bull. 14, pp. 73-76, 1919.

[9] Lowe, E. N., Mississippi Geol. Survey Bull. 12, pp. 76-78, 1915; Bull. 14, pp. 77-79, 1919.

sandstone exposed in the vicinity of Kosciusko, the county seat of Attala County, Miss., and for the unconsolidated sands of the same age in Mississippi. The name "Decatur sand," being preoccupied, will be dropped.

The "Wautubbee marls," which lie at the top of the Lisbon formation in Mississippi, carry the characteristic Lisbon fauna and may be regarded as the equivalent of the upper or typical part of the Lisbon of Alabama, which they closely resemble. For this reason it seems better to regard them not as a member of the formation but as the undivided part of the formation, and the local name is not needed.

The famous sand bed at Claiborne, Ala., which has yielded so many beautiful shells, is now called the Gosport sand. It is the topmost formation of the Claiborne group. It is nowhere very thick and, except for its shells, is not very significant. It contains a few lenses of leaf-bearing clay which suggest correlation with the Yegua formation. The Gosport lies conformably on the Lisbon formation and is overlain by the *Scutella*-bearing bed at the base of the Ocala limestone.

A series of beds of carbonaceous sand and clay, the extension of the Yegua formation of Texas, crosses Louisiana and Mississippi, rapidly thins toward the east, and probably merges with the Gosport sand in Alabama. The correlation of the Yegua with the Gosport is based primarily upon the stratigraphic position of both between the Lisbon and the Jackson, for the paleontologic evidence is inadequate. Of the 14 species of plants recorded from the Gosport sand only 7 are included in the list of 66 from the Yegua.[10]

DEPOSITS OF JACKSON AGE

Deposits of Jackson age form the upper division of the Eocene. They lie conformably above the Claiborne group and below the Vicksburg group (Oligocene). Two formations, the typical Jackson formation and the Ocala limestone, are recognized in this division of the Eocene in Mississippi and Alabama, and they are regarded as contemporaneous.[11] Many fossils are common to the two formations, but each has some peculiar species. The formations differ in lithology.

The Jackson formation in Mississippi consists of two members—the Moodys marl at the base and the Yazoo clay at the top. The Moodys marl contains the celebrated shell bed from which many beautifully preserved fossils have been taken but is not otherwise notable. The Yazoo clay is much thicker and more extensive and is the horizon of *Basilosaurus cetoides*, the "zeuglodon." The Jackson formation extends from the bluffs bordering the Yazoo Delta eastward across Mississippi and into Alabama as far as Tombigbee River, where it merges into the Ocala limestone.

The Ocala limestone extends eastward from Tombigbee River across Alabama and is widely distributed in Florida and southwestern Georgia.

[10] Berry, E. W., The middle and upper Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 92, p. 31, 1924.

[11] Cooke, C. W., Correlation of the deposits of Jackson and Vicksburg ages in Mississippi and Alabama: Washington Acad. Sci. Jour., vol. 8, pp. 186-198, 1918.

CORRELATION OF THE BASAL CRETACEOUS BEDS OF THE SOUTHEASTERN STATES

By Wythe Cooke

SUMMARY

The basal Cretaceous deposits that fringe the inner margin of the Coastal Plain from eastern Alabama to central North Carolina, where they are overlapped by Miocene sands, have been commonly classified as of Lower Cretaceous age and correlated roughly with the Patuxent formation of the Potomac group of Maryland and Virginia. In this paper the evidence on which this early correlation was based is reviewed, later evidence is considered, and the conclusion is reached that all the basal Cretaceous deposits in the area under consideration are of Upper Cretaceous age.

Acknowledgments are gratefully made of the helpful criticism of the manuscript by L. W. Stephenson and of his generous assistance in the preparation of the correlation table.

CURRENT CLASSIFICATION WITH THE LOWER CRETACEOUS

In 1907 Stephenson [1] applied the name "Cape Fear formation" to more or less arkosic and micaceous sands and clays in North Carolina which rest upon the irregularly eroded surface of the crystalline rocks and are separated from the next younger division, now called Black Creek formation, by a marked erosional unconformity. With regard to their correlation, he says:

> No fossils have been found in these deposits. Upon lithologic and stratigraphic grounds the formation is believed to be approximately synchronous with the Patuxent division of the Potomac series of Maryland and Virginia, although it may include a portion of that series younger than the Patuxent proper.

A paper read by William Bullock Clark before the Geological Society of America in December, 1908, contains the following statement:[2]

> Farther southward in North Carolina is the Cape Fear formation (arkosic sands, clays), so called by Stephenson, which is evidently continuous with the Patuxent formation, although the basal beds of the Coastal Plain are transgressed by later formations in southern Virginia and northern North Carolina. No fossils have been found in the Cape Fear formation, but the strata are similar lithologically to the Patuxent farther north and unlike the Arundel and Patapsco.

In later papers Stephenson was induced to abandon the use of the name "Cape Fear" in favor of Patuxent, although there is abundant internal evidence that he was not convinced of the synchroneity of the "Cape Fear" and the Patuxent formations.

In December, 1910, Stephenson wrote the following statement [3] for the "Index to the stratigraphy of North America":

> The basal portion of the Cretaceous deposits in the region included between the Roanoke Valley in North Carolina and the Alabama Valley in Alabama is composed of highly cross-bedded arkosic sands, in general of coarse texture, with subordinate interbedded layers and lenses of light-colored clays of greater or less purity, reaching an estimated maximum thickness of 500 or 600 feet. These have been designated the "Cape Fear" formation in North Carolina by the writer and the "Hamburg beds" in South Carolina by Earle Sloan and have been regarded as the eastward continuation of the Tuscaloosa (Upper Cretaceous) by the Georgia and Alabama geologists.
>
> In the Carolinas these beds are separated from the overlying Black Creek formation by an unconformity. Likewise an unconformity separates them from the overlying Eutaw formation in the Chattahoochee and Alabama river regions in Georgia and Alabama. Geographically the belt in which the deposits occur is separated from the Cretaceous occurrences to the northward in Virginia by an overlap of Miocene beds. However, in all their physical characters they bear a close resemblance to the Patuxent formation, which forms the basal division of the Potomac group in Virginia and Maryland. On account of this physical similarity and because of their supposed buried connection with the Virginia Patuxent, the application of the name Patuxent has been extended to include these North Carolina arkosic beds. The apparent continuity of the North Carolina beds with the similar deposits to the south would, in the absence of known unconformities, seem to necessitate the adoption of the name Patuxent for all the beds in question in South Carolina, Georgia, and Alabama, unless biologic evidence indicating the incorrectness of this interpretation is forthcoming. With one exception no organic remains have been found in these arkosic beds south of the Virginia line. A few poorly preserved plant remains have been collected recently from an exposure in a bluff of Tallapoosa River at Old Fort Decatur, in Macon County, Ala. These were submitted to E. W. Berry, who expressed the opinion that the beds containing them are of Lower Cretaceous age. The meager paleontologic evidence thus afforded tends to confirm conclusions which Mr. Berry and the writer had previously reached, based on physical criteria alone. Unfortunately the poorly preserved condition of the leaves renders it difficult to determine satisfactorily the relation of the formation to the Patuxent formation of Virginia and Maryland. However, in Mr. Berry's opinion, the presence of large numbers of leaves, apparently dicotyledons, most of which are too poorly preserved to permit their specific or even generic determination, seems to justify doubt as to their being as old as the Patuxent formation, in which similar questionably identified dicotyledons are very sparingly represented.

In 1914 Stephenson added: [4]

> Should future discoveries confirm the doubt expressed by Berry as to the Patuxent age of the Lower Cretaceous beds

[1] Stephenson, L. W., Some facts relating to the Mesozoic deposits of the Coastal Plain of North Carolina: Johns Hopkins Univ. Cir., new ser., No. 7, pp. 93–99, 1907.

[2] Geol. Soc. America Bull., vol. 20, p. 647, 1910.

[3] U. S. Geol. Survey Prof. Paper 71, pp. 605–606, 1912.

[4] Stephenson, L. W., Cretaceous deposits of the eastern Gulf region: U. S. Geol. Survey Prof. Paper 81, p. 11, 1914.

of Alabama and Georgia, and should it be found that the Alabama-Georgia Lower Cretaceous deposits are synchronous with the "Cape Fear" formation, it would at once become apparent that the name Patuxent was not appropriate for Lower Cretaceous deposits anywhere south of Virginia.

EVIDENCE OF UPPER CRETACEOUS AGE

My own field work in South Carolina during 1917 and 1922, part of which was done in company with Mr. Stephenson, led me to the opinion that the supposed Lower Cretaceous deposits of South Carolina are really of Upper Cretaceous age. With this in mind, Mr. Stephenson, in 1923, revisited Old Fort Decatur, Ala., and obtained additional collections of fossil plants which, when studied by Professor Berry, proved to be of Upper Cretaceous age, probably of about the age of the Tuscaloosa formation of western-central Alabama.[5] This removes the only paleontologic barrier to the correlation of the basal Cretaceous deposits of the States south of Virginia with the Upper Cretaceous and restores the original correlation made by the Alabama Geological Survey.

My reason for thinking that the basal Cretaceous deposits of South Carolina are of Upper Cretaceous age is this: There seems to be no valid distinction between the so-called Lower Cretaceous or "Hamburg beds" of Sloan and the typical Middendorf beds, which contain a large flora of Upper Cretaceous age.[6] Middendorf lies in the midst of uniform sand hills that extend from the North Carolina line along the southern border of the Piedmont upland to the valley of Congaree River at Columbia. No one has succeeded in separating the "Hamburg" from the Middendorf in this area. The type area of the "Hamburg" is on the east side of Savannah River opposite Augusta and is obviously the continuation of the so-called Lower Cretaceous of Georgia. The lithology in the two areas is very similar.

The Middendorf beds, named by Sloan in 1904,[7] were described ten years later by Berry [8] under the name "Middendorf arkose member of the Black Creek formation." Berry considered the Middendorf a member of the Black Creek because a good many species of plants are common to the two, but in my opinion the differences in the floras are more significant than the resemblances. Of the 65 species from the Middendorf listed by Berry, 39 have not been found in the Black Creek formation in the Carolinas. Stronger evidence that the Middendorf should be considered an independent formation is afforded by the stratigraphy and areal distribution. The Middendorf consists chiefly of light-gray, white, or buff cross-bedded arkosic sand and lenses of white or light-colored clay or kaolin that contrast sharply with the overlying black or very dark clay and sand of the typical Black Creek, from which they are separated by a pronounced unconformity. The area occupied by the Middendorf is much greater than that of the Black Creek in South Carolina, and the type locality of the Middendorf, which lies near the center of its belt of outcrop, is 20 miles from the nearest exposure of the Black Creek formation. It seems fitting, therefore, to restore the Middendorf to the rank of formation. The name Middendorf formation can also be applied to the "Hamburg beds" and to the equivalent "undifferentiated Upper Cretaceous" deposits [9] (formerly called Lower Cretaceous) east of Flint River in Georgia. However, some of the beds in Georgia having the aspect of the Middendorf may be considerably younger than the typical Middendorf of South Carolina. The basal Cretaceous deposits of South Carolina and Georgia, as well as those of Alabama, are therefore of Upper Cretaceous age.

Concerning the basal Cretaceous of North Carolina Stephenson [10] says:

> Although the "Cape Fear beds" appear to be continuous with the Lower Cretaceous arkosic beds of South Carolina [Middendorf formation], Georgia, and Alabama, it is possible that they are not actually continuous; for the irregular character of the bedding, the presence of numerous local unconformities within the beds, and the lack of extensive exposures render the detection of an important unconformity difficult—and such an unconformity may exist.

The discovery that the Middendorf lies unconformably below the Black Creek formation, like the "Cape Fear" formation, is additional evidence that the "Cape Fear" and the Middendorf are of the same age. However, there are certain rather obvious differences in lithology between the beds in North Carolina and those in South Carolina. The beds of the "Cape Fear" formation in their best exposures along Cape Fear River are persistent and generally compact and uniform, but those of the Middendorf formation are variable, lenticular, and usually softer. Yet beds resembling the "Cape Fear" occur at several places in South Carolina, notably at Eureka Mill Pond, 5 miles southwest of Cheraw, and near the Cheraw-Camden road 2 miles west by south of Patrick. At the type locality of the Middendorf formation the plant-bearing clay bed merges into tough argillaceous gray sand resembling the typical "Cape Fear." It seems certain that the "Cape Fear" and the Middendorf are at least in part equivalent.

The following hitherto unpublished note on the "Cape Fear" formation is contributed by Mr. Stephenson:

> On Little River, near old Manchester, on the northern edge of Camp Bragg, Cumberland County, N. C., there are exposures

[5] Berry, E. W., The age of the supposed Lower Cretaceous of Alabama: Washington Acad. Sci. Jour., vol. 13, pp. 433–435, 1923.

[6] Berry, E. W., Upper Cretaceous and Eocene floras of South Carolina and Georgia: U. S. Geol. Survey Prof. Paper 84, 1914.

[7] Sloan, Earle, A preliminary report on the clays of South Carolina: South Carolina Geol. Survey, ser. 4, Bull. 1, p. 75, 1904.

[8] Berry, E. W., op. cit. (Prof. Paper 84), p. 7.

[9] Prettyman, T. M., and Cave, H. S., Petroleum and natural gas possibilities in Georgia: Georgia Geol. Survey Bull. 40, pp. 75–76, 1923.

[10] Stephenson, L. W., op. cit. (Prof. Paper 81), p. 11.

of compact greenish-gray more or less sandy clay interbedded with compact argillaceous arkosic micaceous sand, hard enough, in fact, to be classed as a soft sandstone. These beds are harder and appear more ancient than the more typical "Cape Fear" sediments above them. It is possible that these harder beds may belong to a Cretaceous formation older than the overlying more typical unconsolidated beds of the "Cape Fear," with which they have heretofore been included.

In view of the fact that the "Cape Fear" formation may include more than the Middendorf of South Carolina, it seems best to retain for the present the name "Cape Fear" rather than to extend the use of the name Middendorf, which has priority, to all of the "Cape Fear" of North Carolina. However, the name Middendorf doubtless eventually will be applied to the corresponding deposits in North Carolina. In the light of the present known facts, the name Patuxent obviously can not appropriately be used in North Carolina.

PREFERRED CORRELATION

The precise correlation of the Middendorf with formations west of Flint River can not yet be stated with assurance. Florally, the Middendorf in South Carolina is most closely related to the Tuscaloosa formation, 21 of its 65 species of fossil plants being present also in the Tuscaloosa, whereas only 9 are common to the Eutaw; but as some of the common species have a long range and wide distribution, the number of significant species is less than the figures given. It seems probable that in Georgia the beds having a Middendorf aspect represent a period of time somewhat longer than that of the Tuscaloosa and including part, perhaps all, of Eutaw time. These relations are indicated in the subjoined correlation table, which is based chiefly upon the work of Stephenson.

Correlation of the Upper Cretaceous formations of the Southeastern States

	Western Alabama		Eastern Alabama and Georgia west of Flint River		Georgia east of Flint River and South Carolina west of Congaree Valley	Eastern South Carolina		North Carolina	
	Eocene.		Eocene.		Eocene.	Eocene.		Eocene.	
a									
						Peedee formation.		Peedee formation.	
b									
						Wanting.			
c									
	Selma chalk.		Ripley formation.		Wanting.	Black Creek formation	Snow Hill marl member.	Black Creek formation.	Snow Hill marl member.
d									
	Eutaw formation	Tombigbee sand member	Eutaw formation	Tombigbee sand member ?					
e									?
	Tuscaloosa formation		Tuscaloosa formation.		Middendorf formation.	Middendorf formation.		"Cape Fear" formation.	
								?	
	Paleozoic.		Crystalline rocks.		Crystalline rocks.	Crystalline rocks.		Triassic and crystalline rocks.	

a. Top of *Exogyra costata* zone.
b. Top of *Exogyra cancellata* subzone.
c. Base of *Exogyra costata* zone and *Exogyra cancellata* subzone and top of *Exogyra ponderosa* zone.
d. Top of *Mortoniceras* subzone; the base is not definitely established but appears to be restricted within the Tombigbee sand member of the Eutaw formation.
e. *Exogyra upatoiensis* zone. This zone has not been found in outcrop in the Carolinas but has been recognized near the bottom of a 2,000-foot well at Charleston.

INDEX